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Part II–A

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Section 1. Aggregate National Product
Section 2. Industry

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SECTION 1. AGGREGATE NATIONAL PRODUCT

SOVIET GROWTH RETARDATION: TRENDS IN RESOURCE AVAILABILITY AND EFFICIENCY

BY

STANLEY H. COHN

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SOVIET GROWTH RETARDATION: TRENDS IN RESOURCE AVAILABILITY AND EFFICIENCY

Summary

Through the decade of the fifties the Soviet economy was the leader in growth performance among the principal industrialized nations. The confidence created by this record provided the basis for Khrushchev's vainglorious goal of overtaking the United States as the world's primary economic power. Since 1958, Soviet growth has slipped markedly from an average annual rate of 7.1 percent for the 8 preceding years to a rate of 5.3 percent for the 6 succeeding years. Official optimism has been replaced by frustrating attempts to get the Soviet economy moving again.

While the most glaring retardation has been in agriculture, which has been almost stagnant since 1958, there have also been sharp decelerations in industrial production and construction. Some initial clue to the retardation is found in the peculiar Soviet use pattern of GNP, as compared with the major market economies. It is characterized by the highest share devoted to nonconsumption purposes. While the fixed investment share is high, nearly 30 percent, it is below that of Japan and West Germany. Along with the United States the defense share is double the proportion of the leading continental economies. The U.S.S.R. is also conspicuous in the distribution of GNP by originating sector in that agriculture accounts for a far higher share than in the large market economies. The same conclusion is applicable to distribution of the labor force. In spite of its heavier agricultural orientation the U.S.S.R. has reduced its agricultural income and labor proportions by smaller percentages than any other major nation. This laggard performance provides statistical evidence of the Soviet inability to overcome its agricultural difficulties.

In 1964 the dollar value of Soviet national product was about 47 percent that of the United States and nearly 2½ times as large as the third largest economy—West Germany. In per capita terms it was only two-fifths the size of the United States and about two-thirds as large as that of the major West European economies. The absolute margin of U.S. GNP over that of the U.S.S.R reached a minimum in 1958 and has been widening since that date.

At first approximation the explanation for the retardation in growth can be viewed in terms of rates of increase in employment and productivity. Since there was an increase in the rate of increments to the labor force, the bulk of the explanation must be found in productivity, or the efficiency with which productive factors have been used. Specifically, analysis will be made of the two main productive factors of manpower and capital, and the lesser factor of education. All other factors are encompassed within the residual between trends in the computed outputs and the three measured inputs.

The supply of manpower to the nonagricultural sectors of the economy was sustained from demographic growth in the 1950-58 period; between 1958 and 1964 the delayed impact of reduced wartime birth rates required reductions in the agricultural labor force and an increase in the participation ratio, even though the ratio was already higher than in the market economies. This trend meant a significant increase in an already unusually large female participation rate. Since 1958 the U.S.S.R. has reduced the length of the working year far more than any other major nation to a level below that of the other six major economies. This paradoxical policy might be explained in terms of an official policy to substitute additional leisure for goods in consumption policy.

The rate of increase in investment dropped sharply after 1958. Housing investment has been declining annually since 1959. Although this latter trend has cushioned the deceleration in productive investment, in the years 1961 through 1963 the rate of increase in the latter category fell to 6.7 percent, half of the annual average for the period 1950–58. The low period of investment growth was one in which defense expenditures were rising rapidly. Soviet investment has been channeled heavily to industry and agriculture and much less to the consumption oriented sectors of housing and services than in the market economies.

The decline in the rate of growth of investment has been accompanied by rapidly rising capital-output ratios. This falling return on investment has occured throughout all sectors. Perhaps the principal reason for this unfavorable trend was Khruschev's imposition of a crash program of investment in chemicals, petroleum, and electronics atop an already strenuous effort more traditional in composition. Sharp increases in the volume of unfinished construction and of uninstalled equipment support this hypothesis. There has also been a rapidly increasing rate of depreciation as obsolescence has been accorded increasing recognition. Last, but not least, the competition between investment and defense for similar scarce human and material resources had apparently been resolved in favor of defense during the early sixties.

Education has long enjoyed a high priority with enrollment ratios at the secondary and university levels considerably higher than in Western Europe, though below the United States. After 1958, progress toward expansion of education was halted in order to direct would be students into productive activity. Recently Soviet observers have become aware that short run employment gains have been achieved at the cost of longrun sacrifices in the quality of the labor force.

Projections of Soviet growth have been based on alternative projections of historical production functions. Continuation of the 1958–64 productivity performance assumes no sweeping reforms in economic institutions, but only piecemeal improvisations. If 1958–64 productivity experience is projected on the basis of demographic increases in employment and official Five Year Plan targets for investment, a range of 4.5 to 5.5 percent for annual growth of Soviet GNP emerges. Should the precipitatous decline in productivity of capital be assumed to be a transitional phenomenon, the rate is increased by 0.8 percent per year. This increase would be offset by a likely under-

fillment of the investment program because of understatement of defense expenditures. Implementation of the 35-hour work week would mean virtually no increase in GNP. A most probable alternative, with the assumptions of 1958–64 man-hour and man-year labor productivity performance, an improved capital productivity performance, and a reduced investment growth trend arising from likely underestimate of defense programs, would yield a growth rate range of 4.5 to 5.5 percent per year. Compared with growth projections for the major market economies, Soviet prospects are about average, and at best only about 1 percent above the United States. In such circumstances the margin between Soviet and U.S. gross national products will continue to widen.

Introduction

Soviet leaders have long taken pride in their economic system's growth performance. Until the end of the last decade, detached Western observers, both in government and on university campuses, readily conceded that, abstracting from its many undesirable features, the Soviet approach to economic organization had demonstrated its ability to generate rapid growth. Furthermore, there was high probability of continuation of this success. Khrushchev's vainglorious threat to bury the United States reflected official optimism as to future growth capabilities.

The evidence of the years since 1958 have destroyed this optimistic prospect and replaced it with searching inquiry by the leadership as to how to get the Soviet economy moving again. Analysis of the institutional and organizational aspects of this problem are treated in the contribution of John Hardt, Dimitri Gallik, and Vladimir Treml to this compendium. This chapter will present the statistical record of Soviet performance in comparison with trends in other leading industrialized economies, analyze the factors which have led to retardation, and pose some speculations as to the future course of economic growth.

Comparative Trends in Gross National Product [1]

The year 1958 marks a significant watershed in the curve of Soviet GNP growth. For the 8 years previous real GNP had been rising by

[1] International comparisons of so inclusive and heterogeneous a magnitude as gross national product are fraught with numerous problems of conceptual and statistical comparability. The challenges grow larger as one compares the Soviet economy with the major market economies with the wide diversity of economic resource priorities and structure, the differing concepts of national product, and the differing natures of price systems. Soviet national accounts have been painstakingly constructed by western scholars and government analysts from official Soviet income statistics. Western economists have also devoted considerable effort to adjusting derived Soviet data to accord with conventional western theoretical and empirical standards. The estimates used in this study have adopted the data and procedures used by these western students. No attempt is made in the study to reconstruct their analysis, but instead reference is made to the interested readers to some of their publications. The pioneering publication by a western scholar is Abram Bergson's The Real National Income of Soviet Russia Since 1928, Harvard University Press, 1961. A discussion of some of the problems of comparability between Soviet and western concepts is provided by Morris Bornstein in Joint Economic Committee, Comparisons of the United States and Soviet Economies, 1960. A more recent interchange on some of the more important questions of comparability is provided by Alec Nove, "Two and One-Half Percent and All That," Soviet Studies, October 1964 and the rejoinder by Stanley Cohn in the January 1965 issue of the same journal. The most recent western calculation of Soviet national accounts has been prepared by Abraham Becker, Soviet National Income and Product, 1958–1962, Rand Corp. (RM–4394–PR), 1965.

an annual average of 7.1 percent; between 1958 and 1964 the average fell sharply to 5.3 percent. The most prominent feature of this general retardation has been the stagnation of agriculture (table 1) in which output has failed to maintain pace with increases in population. However, the deceleration in growth of industrial production from nearly 11 percent to less than 8 percent has also contributed heavily to the overall decline. Construction output has risen by less than half of former rate. The only large sector in which growth actually accelerated, but still at a slow rate, was in services. This atypical trend is explained by the considerable defense demobilization in the earlier period and burgeoning space-oriented science outlays in the latter years.

TABLE 1.—*Annual and period growth rates of Soviet GNP and of selected sectors* [1]

Annual rates for GNP [2]		Sector	Average annual rate [2]	
Year	Rate		1950–58	1958–64
1958	9.4	Industry	10.9	7.8
1959	4.9	Construction	13.2	5.8
1960	5.2	Agriculture	5.7	1.5
1961	6.2	Transportation	12.2	9.3
1962	5.1	Commerce	4.0	6.0
1963	2.6	Services	2.4	4.4
1964	7.9	GNP	7.1	5.3

[1] For derivation of growth rates see appendix A.
[2] All rates in this contribution are compound growth rates.

The wide variations in annual rates around the declining trend line since 1958 reflect sharp changes in agricultural output stemming from weather conditions. (With over quarter of total value added in the economy, trends in agriculture exert a large influence on the economy as a whole.) The sharp increase in 1964 therefore, cannot be regarded as any reversal of a falling secular growth trend. If the agricultural reverses of 1965 could be incorporated into the time series, the GNP growth rate would again be small, around 5.0 percent, and the 1958–65 annual average rate just over 5 percent.

If the performance of the Soviet economy is compared with the record of the other six major industrialized nations, its loss of position of growth leadership becomes apparent (table 2). In the earlier period it stood second to West Germany, and at least equal if the large labor influx into the latter country through the Iron Curtain is discounted. Since 1958 Soviet growth has fallen behind that of West Germany, Italy, France, and Japan. In terms of GNP per capita the worsened performance has been particularly large.

The retardation in Soviet economic development has been accompanied by a faster rate of increase in manpower availability, implying an even greater retardation in the increase in efficiency with which this and other factors of production have been utilized (table 3). The fall in the rate of growth in productivity per employee was far larger than in any of the other economies, most of which experienced increased productivity rates.[2]

[2] This measure is in terms of man-years. For recomputation in terms of man-hours, see subsection "labor force" below.

TABLE 2.—*Comparative growth rates of gross national product* [1]

[Annual averages]

Country	Aggregate		Per capita	
	1950–58	1958–64	1950–58	1958–64
U.S.S.R.	7.1	5.3	5.2	3.5
France	4.4	5.4	3.5	4.0
West Germany	7.6	5.8	6.4	4.6
Italy	5.6	6.1	5.0	5.4
United Kingdom	2.4	3.9	1.9	3.1
Japan	6.1	12.0	4.8	11.0
United States	2.9	4.4	1.2	2.7

[1] The annual average rates of growth shown in the table may reflect considerable dispersions around the averages for particular years. The extent of dispersion can be seen in the following tabular presentation of annual rates of increase in GNP from 1958 to 1964.

Country	1958	1959	1960	1961	1962	1963	1964
U.S.S.R.	9.4	4.9	5.2	6.2	5.1	2.6	7.9
France	2.5	2.8	7.3	4.3	6.3	4.3	5.3
West Germany	3.5	7.1	8.9	5.8	4.1	3.2	6.6
Italy	4.4	7.3	6.8	8.3	6.0	4.8	2.9
United Kingdom	1.0	3.6	4.5	3.3	.2	3.5	5.4
Japan	−.1	18.3	13.0	15.8	6.9	8.3	13.9
United States	−1.2	6.7	2.5	1.9	6.1	3.4	4.8

While indicative of trends in the periods being measured, the annual averages should not be construed as indicators of secular growth trend, as they cover too short a time span. Some notion of longer-term trends may be gained by comparing the average annual rates in table 3 with the projected trends in table 22.

Sources: U.S.S.R.: See appendix A.
United States and Western European economies: OECD, Statistics of National Accounts, 1950–61, Paris, 1964. OECD, General Statistics, January 1965. OECD, OECD Observer, August 1965.
Japan: Bank of Japan, Economic Statistics of Japan, 1961. Aforelisted OECD sources.

TABLE 3.—*Comparative trends in GNP—Employment and productivity*

[Annual averages]

Country	1950–58			1958–64		
	GNP	Employment	Productivity [1]	GNP	Employment	Productivity
U.S.S.R.	7.1	1.7	5.3	5.3	2.0	3.3
France	4.4	.4	3.9	5.4	.9	4.3
West Germany	7.6	2.4	5.1	5.8	1.1	4.7
Italy	5.6	1.6	3.9	6.1	.9	5.2
United Kingdom	2.4	.4	2.0	3.9	.6	3.2
Japan	6.1	2.1	3.8	12.0	1.5	10.4
United States	2.9	1.0	1.9	4.4	1.6	2.8

[1] Man-years. For man-hours computation see table 14.

Sources: GNP—See table 2. Employment—Market economies: OECD, *Manpower Statistics, 1950–62*. OECD, *OECD Observer*. December 1964. United Nations, *Monthly Bulletin of Statistics*, January 1966. U.S.S.R.: See table 10.

The analysis of these declining growth trends in output, employment, and productivity will occupy the remainder of this chapter. Trends in each of the major factor inputs—manpower, capital, and education—will be analyzed in terms of volume and factor productivity. Before presenting this core analysis, the comparative use of resources and sectoral structure of GNP in the U.S.S.R. will be con-

trasted with that of other leading countries. Such comparisons should provide interesting insights into the peculiar nature of the Soviet economy. Lastly, projections of future growth will be ventured on the basis of historic and expected trends in factor productivity and factor supply.

Resource Utilization

Trends in Soviet economic development have been strongly influenced by the choices in resource utilization. In table 4, gross national product has been distributed among six end uses for the seven major industrialized economies, following definitions standardized by the Organization for Economic Cooperation and Development.[3] The Soviet estimates have been structured in accordance with the OECD conceptual framework.[4]

The distinguishing feature of Soviet resource allocation is the large share devoted to nonconsumption purposes. The proportionate claim of private consumption, the portion over which individuals can exercise discretion, was the smallest of any major economy in 1963–64, and probably over the entire period since 1950. Conversely, the U.S.S.R. has reserved a larger share of its GNP for purposes serving the aims of the political leadership than has any other major economy. The Soviet economy's orientation toward rapid growth is manifested by the relatively high proportions of available resources devoted to capital investment and to public consumption. The significant growth element in the latter category has been education. While much larger than average, the share devoted to capital investment in the U.S.S.R. was well below that of Japan, about the same as that of West Germany, and only slightly above that of Italy. This position is explained by the allocation to defense, along with the United States, considerably above the proportionate allocations of the other major economies.

Table 4.—*Comparison of uses of gross national product at factor cost, 1963–64*

[Percent of total][1]

Country	Private consumption	Public civil[2] consumption	Defense	Gross fixed investment	Inventory investment	Foreign balance	Total
U.S.S.R.	46.5	11.7	11.3	28.9	1.6	n.a.	100.0
France	59.2	10.5	5.5	23.4	1.3	0.1	100.0
Germany (Federal Republic)	50.4	12.8	5.1	29.1	1.0	1.5	100.0
Italy	56.7	18.1		26.6	1.0	−2.4	100.0
United Kingdom	60.7	12.4	7.0	18.2	.5	1.2	100.0
Japan	48.8	10.4		36.1	6.0	−1.3	100.0
United States	58.9	10.6	10.8	17.9	.8	1.0	100.0

[1] 1964 for U.S.S.R., 1963 for market economies.
[2] Includes Government administration.
n.a.—not available.

Sources: Market economies—OECD, General Statistics, January 1965. Incidence of indirect taxes assumed to rest on private consumption. U.S.S.R.—See app. B.

[3] Organization for Economic Cooperation and Development, "Standardized System of National Accounts," Paris, 1958.
[4] See app. B to this section.

While the interests of the Soviet consumer have been sacrificed as to maximize the growth of physical and human capital and the nation's international power position, the resource competition between the two high priority objectives has been increasingly confounding Soviet planners in recent years. If the period 1958–64 is compared with that between 1950 and 1958, the rate of growth of resource use has declined in all major uses except defense and public consumption (table 5). The deceleration has been particularly large in private consumption and there has been an absolute fall in housing. Evidently, the reduction in growth would have been much larger for productive investment, had not the housing effort been curtailed. The necessity to recoup eventually the deferment in housing construction bodes ill for the future expansion of nonresidential investment and the future increase in GNP.[5] Conversely, if the increase in defense expenditures can be held to more modest rates, additional resources should be released to investment and eventually to consumption.

TABLE 5.—*Rates of increase in principal end-uses of Soviet GNP* [1]

[Average annual rates]

End-use	1950–58	1958–64
Private consumption	7.2	3.8
Public consumption	5.2	6.2
Productive fixed investment	12.0	9.4
Housing	18.0	−.3
Defense	−2.8	6.3
GNP	7.1	5.3

[1] See app. E for sources and methodology.

Comparative consumption trends

The extent to which the Soviet consumer bore the brunt of the decline in economic expansion after 1958 is placed in perspective by comparison of trends in per capita consumption, both private and communal, in the seven leading economies (table 6). Not only was the deceleration in the trend in levels of consumption far greater than in any other major economy, most of which experienced rising trends, but the rate fell to about the lowest of the group. The main factors responsible for so adverse a trend were the stagnation in agricultural production, with consequent effects on food and fiber supplies, and the reduction in housing construction. The Soviet consumer with the lowest living standard in any of the major economies (exclusive of Japan for which information was not available) fell farther behind the levels of his fellow consumers in the market economies.

Comparative size of gross national product

In 1964 the U.S.S.R. was the world's second largest economy with a GNP approximately 47 percent as large as that of the United States (table 7). Its preponderance over the major economies of Western Europe was approximately in the same ratio as that of the United

[5] The draft version of the new 5-year plan projects a 30 percent increase in housing construction compared with the 1960–65 effort.

States over the U.S.S.R. In per capita terms its relative position was much less favorable—about two-fifths of the United States; about two-thirds of that of West Germany, France, and the United Kingdom; about one-twelfth above that of Italy; and nearly 25 percent above Japan's.

As a proportion of the United States equivalent, Soviet gross national product increased from one-third in 1950 to a plateau of around 46 or 47 percent since 1958 (table 8). In terms of the absolute margin of the U.S. economy over the Soviet, the minimum difference was reached in 1958. Since that date, the dollar gap between United States and Soviet GNP has been progressively widening.

TABLE 6.—*Comparative trends in per capita consumption*

[Annual average rates]

Country	1950–58	1958–64
U.S.S.R.	5.0	2.4
France	3.3	3.6
Germany (Federal Republic)	6.3	4.9
Italy	3.1	5.5
United Kingdom	1.6	2.6
Japan	[1] 2.3	7.4
United States	1.1	2.4

[1] 1953–58.

Sources:
Western European countries and United States: European Economic Community, General Statistical Bulletin, November 1965. OECD, Statistics of National Accounts, 1950–61, Paris, 1964.
Japan: OECD source. Ministry of Finance, Quarterly Bulletin of Financial Statistics, December 1965.
U.S.S.R.: See table 8 in contribution of David Bronson and Barbara Severin.
Population: United Nations, Monthly Bulletin of Statistics.

TABLE 7.—*Comparative dollar values of gross national product in 1964*

[Market prices]

Country	Ranked by GNP (billions)	Country	Ranked by per capita (dollars)
United States	629	United States	3,273
U.S.S.R.	293	West Germany	2,154
West Germany	126	France	1,953
United Kingdom	104	United Kingdom	1,910
Japan	101	U.S.S.R.	1,289
France	96	Italy	1,187
Italy	61	Japan	1,040

Sources and methodology:
West European countries: 1964 GNP is originally expressed in the countries' own currencies. They are obtained from the sources noted in table 2. Ratios for converting these estimates are initially based on the 1955 ratios in Milton Gilbert & Associates, Comparative National Products and Price Levels, OECD, Paris, 1958. The geometric means of United States and European weights are used. The ratios are moved to 1964 by the indexes of European prices divided by U.S. prices. The price indexes can be derived from sources used to make the original estimates.
Japan: The same methodology is followed for Japan: 1964 yen estimates are obtained from the source cited in table 2. A 1960 geometric conversion ratio has been constructed by Irving Kravis in Journal of Political Economy, August 1963, p. 327. The ratio is expressed in 1964 prices by the same procedure used for the West European economies.
U.S.S.R.: The same methodology is followed for the U.S.S.R. The base year ruble estimate for Soviet GNP in 1955 is obtained from Morris Bornstein and others, Soviet National Accounts for 1955, Center for Russian Studies, University of Michigan, 1961, pp. 71–72. The 1955 estimate is moved to 1964 by the GNP index computed in app. B. The 1955 geometric conversion ratio has been obtained from Morris Bornstein, "A Comparison of Soviet and United States National Product," Joint Economic Committee, Comparisons of the United States and Soviet Economics, 1959, pp. 385–386. The ratio is moved to 1964 by the ratio of the computed Soviet and United States price indexes.
Population: Issues of the United Nations, Monthly Bulletin of Statistics.

TABLE 8.—*Comparative trends in dollar values of United States and Soviet GNP*

[Billions of 1964 dollars in market prices]

Country	1950	1955	1958	1960	1962	1963	1964
United States	387.0	477.0	487.0	531.0	577.0	599.0	629.0
U.S.S.R.	124.0	174.0	215.0	237.0	265.0	272.0	293.0
Difference	263.0	303.0	272.0	294.0	312.0	327.0	336.0
U.S.S.R. as ratio of United States	32.1	36.5	44.2	44.6	45.9	45.4	46.7

Sources:
United States: U.S. Department of Commerce, Survey of Current Business, August 1965, pp. 25, 27.
U.S.S.R.: 1965 dollar estimate in table moved by index computed in app. table A.

The economic significance of the gap depends on variable being measured. If GNP be considered as a rough quantification of general economic potential, the comparison in table 8 is appropriate. If the concern be with some concept of consumer welfare, the dollar gap between the two economies would be limited to a comparison of consumption and would show an even larger divergence. If the concern be military potential, the best indicator would be industrial production, in which case the gap would continue to narrow.

ECONOMIC STRUCTURE

Gross national product by sector of origin

If the structure of the Soviet economy for 1964 in terms of sectoral origin of GNP is compared with that of the other leading industrial powers (table 9), it emerges as the least developed of the group. The share of national product originating in agriculture is over two-thirds again as large as Italy's or Japan's and several times that of the most advanced nations. The industrial (manufacturing, mining, and electric utilities) share of GNP is below that of all major economies, except the United States, in spite of the high-investment priority this sector has enjoyed. The geographic immensity of its territory explains why its transportation share is the highest, even though the highway network is rudimentary. The unusually low proportions of GNP originating in commerce and services is a striking indication of the low priority accorded to these consumer-oriented sectors.

TABLE 9.—*Comparison of gross domestic product by originating sectors, 1950 and 1963 or 1964*

[Percent of total]

Country	Year	Agriculture	Industry	Construction	Transportation communications	Commerce	Services	Total
U.S.S.R.	1950	35.1	22.3	5.7	5.5	6.7	24.7	100.00
	1964	25.2	33.9	9.2	9.7	5.3	16.5	100.00
France	1950	14.7	41.7	5.6	5.5	12.2	20.4	100.00
	1963	8.7	39.9	7.7	5.0	13.4	25.2	100.00
West Germany	1950	10.4	43.8	5.6	7.3	13.4	19.5	100.00
	1963	5.2	45.0	7.6	6.2	13.4	22.0	100.00
Italy	1950	28.3	34.3	3.0	6.1	9.2	19.1	100.00
	1963	15.2	36.0	7.9	6.9	9.1	24.9	100.00
United Kingdom	1950	5.7	40.4	5.4	8.1	13.9	26.5	100.00
	1963	3.7	40.1	6.5	8.2	11.9	29.7	100.00
Japan	1950	26.0	27.7	4.0	7.4	16.5	18.3	100.00
	1963	13.5	34.5	7.1	7.2	16.2	21.5	100.00
United States	1950	7.9	33.6	4.8	7.0	18.2	28.5	100.00
	1963	4.1	32.3	5.0	6.0	16.2	36.0	100.00

Sources and methodology: West European countries and United States: Whenever possible proportions have been expressed in factor cost, i.e., value added in sectors with indirect taxes deducted. It was possible to obtain Italian, British, and United States estimates in these terms, but French and West German data was available only in market prices, which include indirect taxes. The use of market prices somewhat overstates the sizes of the industrial, commerce, and services sectors and understates the proportions of agriculture, construction, and transportation. The adjustments are not large enough to affect the general conclusions of the text. Sources are OECD, Statistics of National Accounts, 1950–61, Paris, 1964; OECD, General Statistics, January 1965; U.S. Department of Commerce, Survey of Current Business, October 1962 and September 1963.

Japan: Estimates are in factor cost. Sources are Bank of Japan, Economic Statistics of Japan, 1961 and OECD, General Statistics, January 1965.

U.S.S.R.: Whereas the market economy estimates are in current prices, the Soviet estimates are in 1959 prices. The base year factor cost distribution of national product by originating sector is obtained from Stanley H. Cohn, Derivation of 1959 Value-added Weights for Originating Sectors of Soviet Gross National Product, Research Analysis Corporation (TP–210), 1966, p. 20. The 1959 estimates are moved to 1950 and 1964 by sector indexes developed in app. A.

The comparative dynamics of the Soviet economic structure is as distinctive as its current features. In the period since 1950 the U.S.S.R. has reduced the agricultural proportion of GNP by a far smaller percentage than have the other major economies even though its share was largest at the outset. This trend is indicative of the persistence of the agricultural problem. In spite of this handicap, the U.S.S.R. has succeeded in raising its industrial share by the largest relative amount, but this accomplishment occurred at the expense of a sharp proportionate reduction in the services sector, largely through a low priority on housing construction. Such a trend in services runs counter to the normal course of economic development and was attainable only in an economy which paid little heed to consumer sovereignty. By contrast the typical trend in the most advanced market economies has been relative declines in agriculture offset by rises in services with stability in the industrial share. The bulk of the shifts in Soviet economic structure occurred between 1950 and 1959. Since 1959 changes in economic priorities have arrested the decline in the consumer-oriented sectors with the continued reduction in agriculture being absorbed by increases in industry.

Distribution of employment of economic sectors

The conclusions regarding the changing structure of the Soviet economy are verified by analysis of comparative distribution of employment among originating sectors in table 10. The U.S.S.R. continues to be characterized by the highest proportion of its employed labor force in agricultural pursuits.[6] In addition, its proportionate reduction in the farm labor force has been less than that of other major powers, even though it was the most agriculturally oriented at the beginning of the period. If the nonagricultural segment of employment is subdivided into the secondary (manufacturing, mining, utilities) and tertiary (transportation and communication, commerce, and civilian services) groupings, one would expect on the basis of shares of GNP originated that the U.S.S.R. would have the lowest proportion of tertiary employment to the combined secondary and tertiary total. Instead it stands about average among the seven major economies. The explanation for this divergence is the unusually low ratio of tertiary to secondary productivity per employee. This phenomenon is the result of the official policy toward investment and manpower priorities, which have favored industrial over service-type activities. The manpower drain of military requirement has also been proportionately highest in the U.S.S.R. until the late fifties, but by 1962 had fallen lower than that of the United States and France.

TABLE 10.—*Comparison of distribution of employment by economic sector (percentages of total)*

Country	Year	Agriculture	Industry	Construction	Transportation communications	Commerce	Services		Total
							Civilian	Military	
U.S.S.R.	1950	49.7	19.0	3.2	5.6	4.0	12.8	5.7	100
	1958	43.8	22.1	4.6	6.7	4.4	14.4	4.0	100
	1964	36.5	24.4	5.0	7.5	5.4	18.1	3.1	100
France	1954	27.2	28.8	6.9	5.1	11.4	17.0	3.5	100
	1962	19.8	30.0	8.3	5.5	13.3	18.4	4.7	100
Germany (Federal Republic).	1950	24.7	48.5			26.8		0	100
	1962	13.3	53.7			31.6		1.4	100
Italy	1950	40.0	35.8			22.7		2.0	100
	1962	27.4	46.2			24.7		2.0	100
United Kingdom	1950	5.4	42.8	6.3	7.8	13.3	21.4	3.0	100
	1962	4.0	40.4	6.8	6.8	16.1	24.1	1.8	100
Japan	1953	42.4	20.2	4.1	4.4	15.9	13.0	0	100
	1962	29.9	25.0	5.9	5.3	18.5	15.3	0	100
United States	1950	13.2	27.6	5.6	5.9	22.2	22.8	2.7	100
	1962	8.2	25.6	6.0	4.8	24.1	27.3	4.0	100

Sources: U.S.S.R.–U.S. Congress, Joint Economic Committee, Current Economic Indicators for the U.S.S.R., 1965 table VI–2. Same author, Dimensions of Soviet Economic Power, 1962, p. 43. Institute for Strategic Studies, The Military Balance, 1962–63, London. Agricultural employment estimates from table 14 in contribution of Douglas Diamond. Market economies–OECD, Manpower Statistics, 1950–62, Paris, 1963.

[6] This comparison is in terms of annual average man-years of employment. If the measure were numbers of persons, the predominant Soviet margin in agricultural employment would be even larger.

Trends in Factor Availability and Productivity

Labor force

During the two periods under review the Soviet economy has been confronted with rising rates of increments to employment and with a sharp drop in the rate of growth in labor productivity. Since the manpower input is responsible for about 70 percent of factor contributions to GNP,[7] the cumulative damping effect of the foregoing trends on the rate of increase in national product has been considerable.

In the earlier period (1950–58) the demographic situation was favorable to rapid expansion in nonagricultural civilian employment, ample even for an increase of about 0.4 million in agricultural employment and of over 6.6 million in the number of nonparticipants of working age (15 to 64 years). Manpower supply was further enhanced by a reduction of 900,000 in the strength of the armed forces (table 11). The delayed impact of the low wartime and early postwar birth rates on employment became apparent after 1958. Whereas the increase in the working age population was 50 percent larger than the increase in nonagricultural civilian employment prior to 1958, after that date less than half of the employment increment could be supplied demographically.

Table 11.—*Sources of Soviet nonagricultural manpower* [1]

[Thousands]

Years	Civilian [2] nonagricultural employment	Work-age [3] population 15 to 64 years	Total [4] employment	Agricultural [5] employment	Armed [4] forces	Nonparticipants [6]	Participation [7] ratio (percent)
1950	36,778	115,067	82,532	41,054	4,700	32,535	71.7
1958	49,499	133,920	94,767	41,468	3,800	39,153	70.8
1964	64,302	140,137	106,553	38,963	3,300	33,584	76.0
1950–58	12,271	18,853	12,235	414	−900	6,618	−0.9
1958–64	14,803	6,217	11,786	−2,505	−500	−5,569	5.2

[1] Increase in civilian nonagricultural employment equals increase in work-age population plus decrease in agricultural employment plus decrease in Armed Forces plus decrease in nonparticipants. Estimates are level, for 1950, 1958, and 1964; changes for 1950–58 and 1058–64.
[2] Table 5 in contribution of Murray Feshbach
[3] James Brackett (working paper), Estimated Population of the U.S.S.R. by Single Years and Sex—Model 3, Foreign Manpower Division, Bureau of the Census. These estimates have been superseded by later estimates of Mr. Brackett, but were not available when my paper was prepared.
[4] Table 3.
[5] Table 14 in contribution oi Douglas Diamond.
[6] Working age population less total employment.
[7] Total employment as ratio of working age population.

It was therefor necessary to reduce farm employment by over 2.5 million, draw upon a further cut of one-half million in the armed forces, and reduce the number of nonparticipants of working age by nearly 5.2 million. This resort to a higher participation ratio occurred even though the participation rate in the Soviet economy was

[7] Stanley H. Cohn, "Derivation of 1959 Value Added Weights for Originating Sectors of Soviet Gross National Product," RAC–TP–210, Research Analysis Corp., 1966, p. 21.

already considerably higher than in other major industrialized countries. Undoubtedly, part of the explanation for the sharp decline in labor productivity, analyzed later in the text, lay in the resort to marginal manpower from agriculture and nonparticipants.

Indicative of the higher participation rate in the Soviet economy is the larger productive role played by the female population. Not only is the female proportion of total employment higher than in other major economies, but it is also higher in all of the principal economic sectors. Particularly striking is the unusually large role played by women in industry, agriculture, construction, and transportation. Even in sectors in which heavy participation of women is traditional in the West, such as commerce and the services, the Soviet proportions are still the highest (table 12).

With the exception of the United Kingdom with its miniscule agricultural sector, the Soviet Union has been the only major power to have relied on reduction in the number of nonparticipants to supply a significant part of its urban manpower needs (table 13). Part of the explanation is, of course, the unfavorable demographic trend after 1958, but this effect has been compounded by the economy's relative inflexibility in transferring labor out of agriculture. Since 1950 the U.S.S.R. has reduced its agricultural employment by a smaller average annual rate than any other major country—0.4 percent compared with over 2 percent for France, West Germany, and the United States, and between 1.5 and 2 percent for Italy, Japan, and the United Kingdom.[8] Even the 1-percent average annual reduction since 1958 is still smaller than the rates for the other major economies. Thus, the agricultural constraint on Soviet economic progress is evidenced in terms of manpower availability.

TABLE 12.—*Comparative female labor participation, 1960 (proportion of total civilian employment)*

Country	Agriculture	Industry	Construction	Transport	Commerce	Services	Total
U.S.S.R.	61.5	45.0	29.0	29.0	69.0	64.3	53.7
France	39.6	25.3	4.3	17.7	46.1	60.1	37.7
West Germany	53.6	25.3	4.5	23.0	48.8	49.9	36.5
Italy	33.5	24.0	1.2	7.2	32.5	39.7	29.8
United States	9.8	20.9	3.7	8.6	37.7	51.3	32.8

Sources:
U.S.S.R.—Joint Economic Committee, "Current Economic Indicators for the U.S.S.R," 1965, table VII-5. Same publisher, Annual Economic Indicators for the U.S.S.R, table V–A–1.
West European countries—Statistical Office of the European Communities, Informations Statistiques, No. 2 bis, 1963, tables 51 and 60.
United States—Bureau of Census, U.S. Census of Population, 1960—U.S. Summary Detailed Characteristics, pp. 1–563, 1–570, 1–571.

[8] See sources to table 13.

TABLE 13.—*Comparison of sources of nonagricultural employment for selected periods* [1]

[Thousands]

Country	Period	Civilian nonagricultural employment	Work-age population 15 to 64 years	Total employment	Agricultural employment	Armed Forces	Unemployment	Nonparticipants	Participation ratio [2] (percent)
U.S.S.R.	1950–58	12,271	18,853	13,297	414	−900		6,618	71.7–70.8
	1955–64	14,803	6,217	9,074	−2,505	−500		−5,569	70.8–76.0
France	1954–62	1,553	1,406	343	−1,342	233	−81	1,063	70.4–65.8
West Germany	1950–62	6,870	4,247	4,235	−1,555	365	−1,445	6	68.3–70.6
Italy	1950–62	2,833	2,550	2,144	−1,349	49	−1,319	406	60.3–57.8
United Kingdom	1951–62	2,118	1,138	1,687	−241	−385	203	−549	70.6–72.1
Japan	1953–62	9,340	8,410	6,250	−2,960		−130	2,160	74.8–71.6
United States	1950–62	10,405	12,528	9,932	−2,307	1,177	656	2,596	65.7–63.7

[1] Increase in civilian nonagricultural employment equals: plus work-age population plus decrease (minus increase) in agricultural employment, armed forces, unemployment, and nonparticipants. See table 11, definition of items.

[2] Terminal year—1964.

Sources:
U.S.S.R.—See table.
Market economies—OECD, Manpower Statistics, 1950–62, Paris, 1963.

The manpower stringency prevailing since 1958 would appear to be more acute if qualitative labor requirements were taken in account. There has been increasing discussion and official statements as to shortages of highly skilled labor, difficulties in finding employment for teenagers who are inadequately trained for industrial occupations, inadequate vocational outlets for women and low-skilled persons in areas with little structural diversity, and regional imbalances in labor supply and requirements.[9] Much of these qualitative deficiencies have been reflected in the worsening labor productivity performance. If no adjustment is made for changes in working hours, the trend in Soviet labor productivity between the periods preceding and following 1958 are by far the least favorable among the leading industrialized nations (table 3). However, if changes in working hours are considered the Soviet record is still relatively unfavorable, but in much smaller degree (table 14, for after 1958 the length of the workweek was reduced far more in the U.S.S.R. than in any other major economy.

As a result of the reduction in the industrial workweek from an average of 48 hours in 1957 to 41 hours in 1961, the average number of annual man-hours worked in Soviet industry was less than for any of the leading industrial economies. By 1963, the industrial work year in France, Japan, and the United Kingdom was around 20 percent; in West Germany about 17.5 percent; and in Italy and the United States around 5 percent higher than in the U.S.S.R.[10]

TABLE 14.—*Comparative trends in working hours, man-year, and man-hour labor productivity* [1]

[Annual average rates]

Country	1950–58			1958–64		
	Working hours	Labor productivity		Working hours	Labor productivity	
		Man-year	Man-hour		Man-year	Man-hour
U.S.S.R.	−0.5	5.3	5.8	−1.4	3.3	4.7
France	(2)	3.9	3.9	.1	4.3	4.4
West Germany	−.8	5.1	5.9	−.7	4.7	5.4
Italy	(2)	3.9	3.9	−.2	5.2	5.5
United Kingdom	(2)	2.0	2.0	−.2	3.2	3.5
Japan	.6	3.8	3.2	−.6	10.4	11.0
United States	−.5	1.9	2.4	.6	2.8	2.2

[1] Index of man-hour productivity = Man-year productivity index multiplied by index of working hours.
[2] Negligible.

Sources and methodology:
Working hours:
U.S.S.R.—See app. C on "Calculation of Man-Hours Western European Countries and United States," Angus Maddison, "Economic Growth in the West," 1964, table G–1. United Nations, Monthly Bulletin of Statistics, October 1965. In latter publication movement of working hours in manufacturing assumed to be applicable to entire economy.
Japan—OECD, Economic Surveys by the OECD—Japan, July 1964. Cited United Nations source.
Labor productivity: Man-year productivity, table 3.

Paradoxically the sharp transition to so relatively short a working regimen occurred at a time when the average dollar output per em-

[9] Central Intelligence Agency, "Unemployment in the Soviet Union—Fact or Fiction" (CIA/RR ER 66.5), March 1966.
[10] See sources to table 14.

ployee in the Soviet economy was less than a third of the U.S. average and only a little over half of the average for France and West Germany and even below that of Italy (table 15).

TABLE 15.—*Comparative dollar output per employee in 1964*

Country	GNP (billions)	Employment (millions)	GNP per employee
U.S.S.R.	293.0	106.64	$2,750
France	95.5	19.86	4,809
West Germany	125.6	26.19	4,796
Italy	60.6	20.74	2,922
United Kingdom	103.5	25.49	4,060
Japan	100.8	46.14	2,185
United States	638.8	74.68	8,554

Sources: GNP, see table 7. Employment, see table 3.

The decision to reduce working hours at a time of tightening manpower supply and a low ratio of output per employee relative to other leading industrial powers can, perhaps, be rationalized as method of substituting leisure for goods in a situation in which rapid increase in consumer goods production, including housing, was inexpedient. In a period of rising defense priorities and declining productivity of investment, it was not possible to both sustain growth and the country's military posture and maintain consumption goods increases at a rapid rate. There were considerable productivity gains from working hours reductions, as the data in table 15 indicates, but, nevertheless they were not large enough to offset the adverse effects on output of fewer annual man-hours.

The decline in labor productivity growth was not occasioned by stagnation in agriculture, for the nonagricultural sectors of the economy experienced about the same decline in terms of man-hours as the economy as a whole, while that for agriculture was somewhat larger, from 5.1 to 4.5 percent and 6.0 to 2.6 percent respectively. Of course, in man-year terms the deceleration in the nonagricultural sector was considerable, from 4.3 to 2.3 percent, and for agriculture somewhat less, from 5.6 to 2.5 percent.

Capital investment

During the periods under review trends in the physical capital input have exerted a considerable depressing effect on the growth of Soviet GNP. While accounting for less weight than labor in the production function, around 30 compared with 70 percent,[11] the deceleration in both the rate of investment and the return on capital have been greater than comparable trends in employment and labor productivity.

While substantially exceeding the increase in national product as a whole, the rate of increase in capital investment fell by nearly half in the 6 years following 1958, as compared with the 8 preceding years. The behavior pattern was very different if differentiation is made between housing and nonhousing investment. Whereas the deceleration

[11] Stanley H. Cohn, op. cit., p. 21.

in nonhousing investment was only from an average annual rate of 12.0 to 9.4 percent, there was an absolute reduction in residential investment, compared with an average increase of 18 percent from 1950 to 1958. In fact, housing investment declined every year after 1959. Within the nonresidential period average, the rates were particularly low in 1961, 1962, and 1963, averaging only 6.7 percent. For these 3 years aggregate investment averaged only 4.8 percent.[12]

If Soviet investment trends are compared with those of the six other leading economies, recent performance is unfavorable (table 16). In the 8 years prior to 1958 the U.S.S.R. was increasing total fixed investment at a more rapid rate than any of the six major market economies. Since 1958 the U.S.S.R. dropped behind Japan, Germany, and the United Kingdom, and is only marginally ahead of France and Italy. She has held up relatively well in nonresidential investment, but at the price of reduction in housing construction. In this latter respect, the Soviet Union was unique in trend. Given the country's decidedly inferior position in housing standards, the policy decision can only be explained by a desperate effort to maintain economic growth in the face of increasingly adverse underlying circumstances, which will be analyzed in later discussion.

TABLE 16.—*Comparative rates of growth of investment*

[Annual average rates]

Country	Nonresidentical investment		Housing investment		Total investment	
	1950–58	1958–63	1950–58	1958–63	1950–58	1958–63
U.S.S.R.	12.5	9.4	18.0	−0.3	10.8	7.4
France	4.5	7.0	11.6	7.4	5.5	7.1
West Germany	10.6	10.3	8.0	7.5	9.6	8.4
Italy	6.2	6.4	15.6	8.6	8.2	6.9
United Kingdom	4.7	6.7	7.5	10.7	4.4	7.4
Japan	n.a.	n.a.	n.a.	n.a.	7.7	20.0
United States	1.6	5.4	.7	.28	1.3	4.6

N.a.—Not available.

Sources: West European countries: OECD, "Statistics of National Accounts, 1950–61," Paris, 1964. European Economoc Community, "General Statistical Bulletin," November 1965. "National Institute Economic Review," August 1965. OECD, "General Statistics," January 1965. United States: Foregoing OECD sources and "Survey of Current Business," August 1965. Japan: Foregoing OECD sources and Ministry of Finance, "Quarterly Bulletin of Financial Statistics," December 1965. U.S.S.R.: "Current Indicators, for the U.S.S.R.," table IV–1. "Narodnoe khoziaistvo SSSR v 1964 godu," pp. 513–514.

Direction of investment

While the proportion of resources devoted to investment in the Soviet economy is not distinctly large, the composition of investment is unique and provides clear indication of allocation priorities and some partial explanation for the declining rate of return on investment. If the composition of Soviet investment is compared with that of other leading economies, several distinctive features stand out (table 17).

[12] "Current Economic Indicators for the U.S.S.R.," table IV–1. "Narodnoe khoziaistvo SSSR v 1964 godu," pp. 513–514.

TABLE 17.—*Comparative composition of capital investment*

[Proportions of total]

Country	Period	Agriculture	Mining, manufacturing construction	Utilities	Transportation and communication	Housing	Other	Total
U.S.S.R.	1950–58	15.9	35.3	5.3	8.5	21.3	13.7	100.0
	1959–64	15.8	34.0	4.2	9.7	19.9	16.5	100.0
France	1958–63	6.2	29.6	9.2	14.3	25.0	15.6	100.0
West Germany	1950–57	6.0	31.4	6.5	14.8	23.4	17.8	100.0
	1958–63	6.0	30.4	4.9	14.3	22.3	22.1	100.0
Italy	1950–57	12.9	26.6	6.6	15.6	23.1	15.2	100.0
	1958–63	10.7	25.6	5.3	16.1	26.6	15.8	100.0
United Kingdom	1950–57	4.1	30.8	11.6	11.6	22.2	19.7	100.0
	1958–63	5.3	28.8	11.2	11.3	18.3	25.1	100.0
United States	1950–57	6.0	22.5	7.6	8.1	28.7	27.1	100.0
	1958–63	4.7	19.2	7.4	7.8	30.8	30.0	100.0

Sources: Market economies—OECD, "Statistics of National Accounts, 1950–61, Paris, 1964. OECD, "General Statistics, January 1965. U.S.S.R.—"Kapital'noe Stroitel'stvo," Moscow, 1961, pp. 44, 152, 164, 170, 188. "Narodnoe Khobioistvo SSSR v 1964 godu," pp. 511–515.

Agriculture claims a far higher share of capital resources than in any other major economy, testifying as to the persisting nature of the farm problem, although also a function of the policy of economic autarky. The high priority accorded to industry is reflected in the proportion under this heading, the highest of the six countries. The relatively low transportation share is largely explained by the absence of a highway building program, with its consumer orientation. The housing proportion is relatively small and has shrunk further, even though housing standards are far below those of other major economies. The sundry "other" category is a conglommerate of growth and defense oriented activities like science and education and consumer oriented functions as commerce, municipal services and health. As expected, it is also relatively low, but has been rising markedly since 1958. Two-thirds of the increase in its proportion since 1958 is accounted for by intensified investment in science and, perhaps education.[13]

If the international comparison is structured in terms of types of investment instead of sectoral distribution, another distinctively Soviet pattern emerges. The proportion of total investment consisting of nonresidential construction is much higher and that of machinery and equipment much lower than in any of the market economies.[14] In fact, in the West European economies the equipment proportion is considerably higher and in the United States the proportions are about equal, while the reverse ratio prevails in the U.S.S.R. To some extent this diversity may represent relative price differences,[15] but it is also

[13] "Narodnoe khoziaistvo SSSR v 1964 godu," p. 514.

[14] The Soviet estimates are adjusted to the Western concept which classifies installation costs under equipment rather than construction, as in Soviet statistics. The adjustment of 10 percent of equipment expenditures is used, based on a Soviet calculation. (L. I. Nesterov, "Kapital'nye Vlozheniia SSSR i SShA," Moscow, 1965, p. 97.)

[15] If the 1955 purchasing power of the leading West European currencies relative to the dollar be assumed as unity for GNP, then their purchasing power for machinery and equipment was only two-thirds to three-quarters as great (Milton Gilbert and Associates, "Comparative National Products and Price Levels," Paris, 1958, pp. 40, 86–87); while for Soviet rubles it was 1.85 times larger (Morris Bornstein, "A Comparison of Soviet and United States National Product," Joint Economic Committee, "Comparisons of the United States and Soviet Economies," Washington, 1959, p. 386). For construction the reverse relationships exist.

reflective of the inability of the Soviet economy to devote more equipment type resources to investment purposes. Most likely the impact of heavy defense expenditures is most acute with respect to competition for equipment producing and innovating resources. The long standing disregard of obsolescence, reversed only in the last few years, contributed to a low equipment effort by delaying replacement relative to western practices. Since 1960 there has been a steady rise in the equipment share of nonresidential investment [16] matched by increases in depreciation rates to more realistic levels.[17] Even these new higher rates are considered to be inadequate by Soviet economists, as evidenced by outlays for capital repair in 1964 exceeding depreciation charges by 60 percent.[18]

Capital-output ratios

Both the trend in investment and its functional composition have been unfavorable to economic growth. These trends have been compounded by trends in the productivity of investment, as measured by the capital-output ratio, i.e., the number of units of investment required to produce an additional unit of national product or net output of an economic sector. If the investment variable in an international comparison be limited to nonresidential investment on the grounds that housing with its long life yields a low return, the Soviet record since 1958 has been by far the most unfavorable of any major nation (table 18). While several countries managed to lower their ratios (increase their investment return), the Soviet ratio rose by over half. Whereas prior to 1958 the U.S.S.R. was enjoying, along with West Germany, the highest rate return on investment (lowest capital-output ratio) since 1958 its return has been the lowest except for the United Kingdom. Should the comparison be framed in terms of investment per employee in order to remove the influence of increase in employment on growth, the Soviet relative performance is clearly the poorest. Not only does the amount of fixed investment required to achieve a unit increase in output per employee rise more sharply than in other economies—in four of the countries the ratio falls—but the investment return for the U.S.S.R. in this measure falls from the highest to the lowest of the major economies.[19]

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[16] "Narodnoe khozialstvo SSSR v 1964 godu," p. 513.
[17] Ibid., p. 146.
[18] A. Notkin, "Increase in Effectiveness and Proportions of Social Production in the 5-Year Plan," Planovoe Khozialstvo, June 1964.
[19] The first measure of investment per unit of output is biased in favor of economies with rapid growth in labor force, as it assumes that the marginal productivity of labor unequipped with additional capital is zero. The second measure in terms of return per employee is biased in favor of countries with slow growth in labor force as it assumes that the marginal productivity of labor is equal to its average productivity. Since both of these assumptions represent opposite extremes, the true marginal productivity of labor lies somewhere in between. Since both measures show the Soviet Union in last position in terms of trends in return on investment, the conclusion is well sustained. For a cogent presentation of this thesis see United Nations, Economic Commission for Europe, "Some Factors in Economic Growth in Europe during the 1950's," Geneva, 1964, pp. II–32 and II–33.

TABLE 18.—*Comparative incremental capital-output ratios*

Country	Aggregate [1]		Per employee [2]	
	I—1950–57, O—1951–58	I—1958–63, O—1959–64	I—1950–57, O—1951–58	I-1958–63, O—1959–64
U.S.S.R.	2.1	3.3	2.8	4.9
France	3.0	2.8	3.3	3.5
West Germany	2.0	3.2	2.9	4.1
Italy	2.5	2.7	3.6	2.9
United Kingdom	4.5	3.4	5.7	4.5
Japan [3]	3.3	2.5	4.0	2.9
United States	4.1	2.8	6.2	4.5

[1] Increase in fixed nonhousing investment required to obtain a unit increase in gross national product. A lag of year between a unit of investment (I) and of output (O) has been assumed. Thus, investment for the 1950–57 period is assumed to affect output for the period 1951–58. Similarly investment for the period 1958–63 is compared with output for 1959–64. The ratio is increased to the extent that unutilized capacity exists. Thus the apparent decrease in the U.S. ratio in the latter period reflects the utilization of capacity idled during the 1958 recession.

[2] Same as the aggregate measure except that output is compared with investment per employee.

[3] Total investment, including housing.

Sources: See table 3.

This rise in the overall capital-output ratio cannot be simply explained by stagnation in agricultural progress, for the trend has been evident in all economic sectors, except for a residual grouping covering commerce and the services. The ratio in the key industrial sector showed a sharp increase from 2.3 to 3.5 between the two time periods. In international terms Soviet comparative preformance was much the same as in the GNP capital-output ratio; i.e., by far the most rapid increase and from the lowest ratio to the highest, except for the United Kingdom. If investment be measured in per employee terms the rise in the ratio is over double, from 3.5 to 7.8. This latter trend would indicate that large infusions of manpower were necessary to sustain even a reduced rate of industrial expansion after 1958.

The shift in the distribution of investment between the two periods would have resulted in a slightly reduced GNP capital-output ratio had there been no changes in the individual sectors ratios themselves. If the percentage changes in each sector are weighted by the early and late periods distributions of investment, respectively, the later period weighting would show a decline of around 4 percent in the overall ratio. Since the ratio for GNP nearly doubled, there must have been common factors leading to declines in the return on investment in most sectors of the economy. What are some of the factors which have caused so rapid a decline in productivity of investment?

The agricultural sector trend can be summarized by the stagnation in output, the causes of which are analyzed in the essay of Jerzy Karcz in this compendium. Also, unlike other sectors, there was considerable substitution of capital for labor in the 1958–64 period. However, it is the trend in the industrial sector which has greatest implications for the economy and which arouses concern among the leadership. The possible explanations for the rising industry capital-output ratio include both technical and policy factors.

The industrial capital-output ratio rose by nearly two-thirds after 1958, as compared with the average of the 8 preceding years. This rise was accompanied by significant shifts in the structural composition of industrial investment. The nature of the shift, particularly

away from coal as an energy source, in itself actually contributed to a decline in the capital-output ratio.[20] Therefore, there must have been significant increases in ratios for most industrial branches.

The implementation of Khrushchev's decision to move from the coal and steel to the petrochemical and sophisticated machinery age was implemented abruptly with little attempt to phase out existing investment programs or to give Soviet scientists, engineers, and managers sufficient opportunity to assimilate the new technologies. While industrial investment as a whole increased by 67 percent from 1958 to 1964, investment in oil and gas, chemicals, and machinery rose by 87 percent, 328 percent, and 106 percent, respectively. By contrast, investments in coal increased by only 2.5 percent, and in construction materials by 34 percent.[21] This sudden and abrupt shift led to suspension of many existing projects, thereby raising the capital-output ratio.[22] Meanwhile the inevitable inability of assimilating the new technologies in so short a period of time led to delays in translating investment intentions into production realities in the newly favored branches.

The problems of implementation are reflected in the trends in unfinished construction. Whereas for industry as a whole the volume of noncompletions increased by 80 percent between 1958 and 1964, the increases were 128, 320, and 126 percent for oil and gas, chemicals, and machinery, respectively.[23] Another indicator of the worsening problem of investment gestation was the increase in stocks of equipment waiting installation. While industrial investment rose by 20 percent between 1961 and 1964, equipment investment rose by 35 percent, and stocks of equipment awaiting installation by 88 percent.[24]

Another factor contributing to the increase in the capital-output ratio has been the rising proportion of replacement in gross investment. In part, the trend is statistical rather than real, as outlays for repair of existing facilities are not classified within the Soviet definition of fixed investment. However, to the extent that new or modernized equipment are substituted for repair of older equipment, there is a real economic advantage. An estimate by a Soviet economist shows an increase in the replacement share of economywide investment from 15.6 percent in 1960 to 22.9 in 1963.[25] For productive investment only the proportion rose from 16.6 percent in 1958 to 27 percent in 1964.[26] This trend has been matched by large increases in depreciation rates in 1963, amounting in industry to a 41-percent increase.[27] Even at these higher rates the share of depreciation in gross investment of 22.9 percent in the U.S.S.R. is low by international standards, with the share 30 percent in West Germany and 60 percent in the United Kingdom and the United States.[28] This abnormally low

[20] Ya. B. Kvasha, "Capital-Output Ratio," "Proizvodstvo, nakoplenie, potreblenie" Moscow, 1965, p. 158. The same conclusion has been obtained by the author of this article from independent calculations based on analysis of official investment estimates and net output estimates of western scholars and U.S. Government research organizations.
[21] "Narodnoe khoziaistvo SSSR v 1964 godu," Moscow, 1965, p. 516.
[22] "Kvasha," op. cit., p. 124.
[23] "Narodnoe khoziaistvo SSSR v 1964 godu," p. 523.
[24] A. Riznik, "Combined Accounting Balance of Equipment and Machinery," Vestnik Statistiki, No. 6, 1965, p. 3.
[25] "Kvasha," op. cit., p. 119.
[26] T. Khacheturov, "Increased Effectiveness of Capital Investment and the Scientific Basis for Its Determination," Voprosy Ekonomiki, No. 2, 1966, p. 5.
[27] E. Ivanov, "New Amortization Norms in U.S.S.R. Industry," Voprosy Ekonomiki, No. 10, 1965, p. 33.
[28] A. Notkin, "Increase in Effectiveness and Proportions of Social Production in the 5-Year Plan," Planovoe Khoziaistvo, No. 6, 1964, p. 3.

proportion is confirmed by the phenomena of capital repair outlays in industry in 1964 seven-eighths the magnitude of replacement expenditures.[29] Depreciation rates should thus continue to rise, both because of an aging capital stock and increased recognition of obsolescence.

A more intangible factor affecting the efficiency of investment is that of organization. In recent years the cycle of construction of industrial enterprises in the U.S.S.R. has required 5 to 7 years;[30] by contrast the average time in the United States by a Soviet estimate is only 2 years.[31] The U.S. ratio of uncompleted construction to gross investment is only half the Soviet.[32] The trend, as distinguished from the level of administrative inefficiency, cannot be measured, but it has likely worsened with the growing complexity of investment. Soviet officials are aware that many of the organizational problems which plague industry are also prevalent in construction, but as of the present date, no action has been taken to make incentives more effective.

The degree to which the demands of the defense effort in recent years has influenced the trend of efficiency in investment cannot be calculated without further disaggregation and analysis of information of the type provided in the 1959 Soviet interindustry table.[33] As a substitute, one may deduce the impact by considering the mutual nature of crucial inputs into both defense and investment programs. The desire to maintain some semblance of defense parity with the United States has obliged the Soviet Union to embark on a large scale military research and development effort. The support of such an effort requires large numbers of the country's best scientists, engineers, and production managers, as well as large quantities of highly sophisticated materials and components. The United States has exhibited the capability of simultaneously engaging in a massive military research and development effort and pursuing technological development in civilian oriented activities. Comparable Soviet resources are too limited to duplicate U.S. performance, with the apparent decision being to concentrate on military development. The result has been to both reduce the rate of investment and to lower the efficiency of the decelerated investment effort.[34]

Education

The two main factors of production, labor and capital, are not exhaustive, leaving a residual between trends in their growth and that of output. One factor among these unspecified ingredients in growth

[29] "Narodnoe khoziaistvo SSSR v 1964 godu," p. 146.
[30] O. Nekrasov, "Branch Principles of Industrial Administration and Technical Progress," Voprosy Ekonomiki, No. 11, 1965, p. 10.
[31] "Kvasha," op. cit., p. 126.
[32] Ibid.
[33] Vladimir G. Treml, "The 1959 Soviet Intersectoral Flow Table, Research Analysis Corporation" (TP–137, 1964). Also in summary form in Joint Economic Committee, "Annual Economic Indicators for the U.S.S.R.," 1964, pp. 185–213.
[34] Direct verification of this conclusion from Soviet sources cannot be expected. However, one of the leading members of the rising school of Soviet mathematical economists, A. G. Aganbegian, the director of the Novosibirsk Institute of Economics, is alleged to have made a speech to leading Soviet officials which was highly critical of the current state of the economy. Among other startling remarks he asserted "We spend a great deal for defense and we have much difficulty in competing with the United States in this field because we must spend almost as much as they do while our economic potential is only half of theirs. Of about 100 million of the active population, about 30 to 40 million work for defense." This statement was published in the Italian Journal Bandiera Rossa in the July 1965 issue.

of national product which is capable of measurement, given adequate statistical reporting, is education. This factor may be described as either the qualitative adjustment of the labor force or as the human equivalent of physical capital. Soviet planners have long recognized the vital role education plays in economic growth and have granted it a high resource priority, comparable to that enjoyed by capital investment. This emphasis can be illustrated by a comparison on enrollment ratios, the proportions of given age groups in the population enrolled in school, at the two upper levels of education (table 19). While beneath U.S. ratios, the Soviet ratios are well above those of the major Western European countries.

If the considerably heavier than average emphasis of the Soviet Union on secondary and higher education in the late 1950's is compared with the relative per capita income level of that country,[35] the educational effort appears to be disproportionately large. Trends since 1958 would still favor the educational effort of the U.S.S.R. compared to those of the major West European economies. Furthermore, the present relatively high Soviet enrollment ratios have been attained in a much shorter period, over the past 30 years, than is the case in Western Europe. Education has been an important factor in the rapid growth of the Soviet economy from 1929 to the present.

TABLE 19.—*Comparative enrollment ratios* [1]

Country	Secondary (15–19)	Higher (20–24)
U.S.S.R.	48.6	8.2
France	30.8	3.8
Germany (Federal Republic)	17.6	4.6
Italy	15.7	3.9
United Kingdom	17.6	3.9
United States	66.2	12.0

[1] 1958, except 1957 for Italy and United Kingdom.

Sources: OECD, "Policy Conference on Economic Growth and Investment in Education," pt. II; "Targets for Education in Europe in 1970," p. 108.

Turning to more recent trends, we find that recent educational trends have been instrumental in reducing the growth rate for GNP. Education in this measurement is expressed as the capitalized value of the varying levels of educational attainment of the employed population on the terminal dates of the trend comparisons. This procedure is analogous to the method used to capitalize the value of fixed investment.[36] In the period 1950–58 educational stock was increasing by an annual average rate of 7.1 percent; for the period 1958–64 the rate declined to 4.7 percent. In terms of educational stock per employee the deceleration was even sharper, from 5.2 to 2.6 percent.

The decelerating trend in educational inputs stemmed from both demographic and policy factors. The greater than average declines in the growth of enrollments at the elementary level can be explained by the near saturation rate of enrollment at the beginning of the period.[37] The growth rates in educational attainment at the secondary

[35] See table 7.
[36] See app. D, "Derivation of Growth of Educational Stock."
[37] "Dimensions of Soviet Economic Power," p. 241.

and higher levels was based on policy decisions strongly influenced by demographic factors. From 1957 through 1962 the effects of the drastic wartime decline in births had full impact on the size of the 15 to 19 age group from which new entrants to the labor force were drawn, with a decline from 22.1 million in 1956 [38] to 11.9 million in 1962.[39] Although enrollment ratios in 1958 were low enough to permit expansion at a continued rapid rate, constriction of labor supply for productive employment led the regime in 1958 to reverse previous educational policy of expanding secondary educational standards and to channel into remunerative employment elementary school graduates who would have otherwise begun secondary education. Entry into higher education was made contingent on completion of 2 years of productive work experience. In 1964 the length of secondary education was reduced by a year and certain higher education courses were shortened.

Within both higher and specialized secondary (technician training) education the rising proportion of part-time students absorbed the bulk of increased enrollments. In higher education of the total enrollment increase of nearly 1.5 million, less than a quarter were full-time students.[40] As a result of the prolonging of the period required for a degree, the level of graduations showed little change, rising by only 63,000 about 20 percent, between 1958 and 1964, with a 40,000 decline in matriculation of full-time students. In specialized secondary education, the number of graduates was about constant, with a decline of 150,000 in full-time graduates.[41] In addition to registering discontent with slowdown in the supply of graduates, Soviet officials have also expressed concern about the sacrifice in quality arising from the stress of part-time training.[42] It would therefore appear that Soviet educational policy has sacrificed longrun growth in favor of near-term manpower gains. The new 5-year plan has apparently restored the goal of universal secondary education.

Future Growth Prospects

Historical production functions

The recently announced 5-year plan for the years 1966–70 provides the framework of official intentions upon which to base judgments as to future growth prospects. These judgments must rest fundamentally upon the evidence of recent performance. Given the condition of full, or even overemployment, of resources by Soviet planners, the key variables are those which affect the supply of resources—manpower, capital, education, and other unspecified inputs. Trends in these inputs have already been analyzed in detail, but they will now be presented in summary fashion in a production function for the Soviet economy. Trends in gross national product can be analyzed in terms of trends in the basic factor inputs. In the form of an equation it is a simplified version of the Cobb-Douglas type: $L+K+R=P$, or $L+K+E+R=P$, where L is labor in man-hours, K is capital, E

[38] "Dimensions of Soviet Economic Power," p. 555.
[39] "Current Economic Indicators for the USSR," p. 38.
[40] "Narodnoe Khoziaistvo SSSR v 1964 godu," p. 678.
[41] Ibid., p. 686.
[42] Pravda, Aug. 31, 1965. Statement of M. Prolofiev, First Deputy Minister of Higher and Specialized Secondary Education.

is education, R is the residual containing other unspecified factors, and P is gross national product. The equations can be quantified for the 1950–58 and 1958–64 in models including and excluding the educational input (table 20). The magnitudes are average annual rates of increase.[43]

TABLE 20.—*Soviet GNP production functions (annual average rates of increase)*

Period	L	K	R	P	
1950–58	1.2	8.3	3.7	7.1	
1958–64	0.6	9.4	2.0	5.3	
	L	K	E	R	P
1950–58	1.2	8.3	7.1	3.2	7.1
1958–64	0.6	9.4	4.7	1.6	5.3

The R entry may also be regarded as the joint factor productivity of the measured variables. Since it is the unexplained portion of growth, its size decreases with the increase in the number of measured factor inputs. If a man-year measure of labor is used, the L rates become 1.7 and 2.0. The R factor in the equation without education becomes 3.4 and 1.1, and in the one containing education becomes 2.9 and 0.8. Thus, on a man-hour basis the downward trend in joint factor productivity is much less.

The projection technique will follow this procedure combining estimates of rates of increases in labor and capital with judgments as to likely productivity trends. The historic trends in joint factor productivity cannot be used directly, as they are dependent on trends in the factors themselves and to the extent factor trends diverge from historic performance, the joint productivity trends would be affected. Therefore, it is also necessary to derive historical estimates of partial productivity trends for each of the factor inputs (table 21).[44]

TABLE 21.—*Soviet GNP partial productivity trends (annual averages)*

Period	L (man-year)	L (man-hour)	K	E
1950–58	5.3	5.8	−1.2	nil
1958–64	3.3	4.7	−3.7	1.2

Projected alternative growth estimates

Through 1970 the population in the prime working age group (16 to 59 for men and to 54 for women) is expected to increase at an average annual rate of 1.4 percent.[45] The rate rises to 1.8 percent in the following 5 years, and falls back to 1.6 percent for the 1975-80 period. Given the unusually high participation rate, it is unlikely that the rate of increase in employment will exceed that of the labor force. The draft of the 5-year plan projector gross capital investment at an implied average annual rate of increase of 8.7 percent.[46]

[43] The sources of estimates have been previously noted in the tabular presentations accompanying discussions of trends in the three specified inputs.
[44] Computed as index of GNP divided by index of factor input.
[45] James Brackett, "Demographic Trends and Population Policy," in Joint Economic Committee, Dimensions of Soviet Economic Power, 1962, p. 521.
[46] Izvestiya, Feb. 20, 1966.

In recent years the retirement rate for fixed assets has been approaching 3 percent.[47] If this rate be assumed to prevail through 1970, the average annual rate of increase in capital stock will be 7.9 percent. For every percentage increase in the retirement rate, the rate of increase in capital stock will be reduced by about 0.8 percent.

If the official investment plan, the existing 3-percent retirement rate, the labor force parameter on employment growth be assumed, several GNP growth rate alternatives may be derived from alternative partial factor productivity assumptions. No attempt will be made to estimate growth of educational stock.

Projections of productivity trends are largely contingent on judgments as to changes in the efficiency of Soviet economic institutions. The companion article in this compendium by Hardt, Gallik, and Treml foresees no fundamental reform in economic organization, but only piecemeal improvisations with little reduction in the degree of centralized direction of the economy. In the light of this conclusion it appears unlikely that any improvement can be expected over the factor-productivity trends for the 1958–64 period.

If the productivity trends for capital and for manpower in man-hour terms for the period 1958-64 are projected for the years 1964-70, the GNP growth rate would be 5.5 percent per year. As a lower limit, if it be assumed that labor productivity will continue the man-year trend, the GNP growth rate would be reduced to 4.5 percent. The best estimate would lie between the two limits, as the man-hour rate was influenced by the stimulative effect of the reduction in working hours and the man-year rate assumes continuation of the workweek reduction policy.

If we assume that the unusually large negative capital productivity trend of the 1958-64 period was largely a result of the drastic shift in the structure of industrial investment by Khrushchev and therefore will be modified as the new technologies are assimilated, a somewhat higher growth rate can be projected.[48] Assuming that the capital productivity trend for the 1950-58 period would prevail and that the growth limits are again set by the man-hour and man-year trends of the 1958-64 period, projected GNP would rise within a range of 5.3 to 6.3 percent.

The target of the 35-hour workweek has not been reaffirmed in the 5-year plan draft. If the old goal were implemented by 1970, there would be no increase in GNP, given the assumptions of projection of the 1958–64 productivity trends.

Some caution should be introduced as to the feasibility of the official investment plan. The proposed 8.7 percent average annual rate has been attained only once since 1959, in 1964. It would appear to be negatively correlated with trends in defense expenditure. Therefore, attainment of the projected official investment rate must be premised on a slower rate of increase in defense outlays than prevailed between 1959 and 1963. Each percentage point shortfall in investment will lead to a reduction of 0.3 percent in the GNP growth rate, and per-

[47] Kvasha, op. cit., p. 119.

[48] The decline in the marginal productivity of capital has apparently been persistent throughout the entire period of centralized planning in the U.S.S.R., according to Prof. Abram Bergson (Abram Bergson and Simon Kuznets, Economic Trends in the Soviet Union, 1963, p. 6). However, by Bergson's historical comparisons, the 1958–64 decline is unusually large.

haps as much as 0.5 percent if the effect on labor productivity is included.

What conclusions can be drawn from these alternatives and qualifications? The extrapolated investment and labor force would appear to be optimal expectations, given continued pressures for maintaining some defense parity with the United States and the high rate of labor force participation. On the other hand, the very poor investment productivity performance since 1958 may be due, in part, to transitional factors. There is no recent indication of further reduction in working hours.

As a most probable expectation, assume that the range of labor productivity will continue to lie within the limits set by the 1958–64 trends in man-hour and man-year output. This assumption, as previously noted, leads to a 4.5- to 5.5-percent growth rate. Further assume that the decline in productivity of capital will be reduced to a rate midway between the 1950–58 and 1958–64 trends, or around —2.4 percent. This change would increase the annual growth rate by about 0.5 percent. Finally, assume that the increase in capital stock will fall somewhat below plan, about 6.7 instead of 7.9 percent. This shortfall would have the effect of neutralizing the growth inducement of improvement in capital efficiency. Therefore, the original 4.5- to 5.5-percent average annual increase in GNP remains the most probable. Should the average annual increases in defense outlays be limited to the 4-percent estimate for 1964, the resulting reallocation to investment would yield an additional 0.5 percent rise in the annual GNP growth limits.

If this projection of Soviet GNP growth is compared with that of the other six major economies for the remainder of the decade, the prospects for the U.S.S.R. appear to be average to somewhat above average (table 22). Soviet growth will be considerably below that of Japan, about equal to that of France and Italy, marginally ahead of that of West Germany, and, at best, only 1-percent greater, and, at worst, equal to that of the United States. In terms of the dollar comparison presented in table 7, the absolute margin of U.S. GNP over that of the U.S.S.R. would widen to $415–438 billion, and the ratio of Soviet to U.S. output would be 47 to 49 percent.

TABLE 22.—*Comparative projections of GNP (annual averages)*

Country	Projected growth rate 1960–70	Performance 1960–65
U.S.S.R.	4.5–5.5	4.9
France	5.0	4.8
West Germany	4.1	4.8
Italy	5.6	5.2
United Kingdom	3.3	3.4
Japan	7.2	9.1
United States	4.5	4.6

Sources:
Projections: For the European OECD countries and the United States the rates represent official national projections of growth within the overall OECD target of 4.5 percent (OECD, Policies for Economic Growth, Paris, 1962, p. 28). The projection for Japan is the official plan goal (Japan, Economic Planning Agency, New Long Range Economic Plan of Japan, 1961–70, Tokyo, 1961, p. 2). The U.S.S.R. projection range has been computed in the text.
Performance: For the European OECD countries and Japan-OECD, General Statistics, January 1965; European Economic Community, General Statistical Bulletin, November 1965; Economist, Jan. 1, 1966. For the United States—the above sources and Survey of Current Business, February 1966. For the U.S.S.R.—Table 1 and estimate for 1965 based upon preliminary calculations of industrial and agricultural performance and assumption of continuation of 1964 rate of growth for other sectors.

Appendix A. Derivation of Index of Soviet Gross National Product

The index of Soviet GNP is composed of the net output indexes of the seven component sectors of origin, weighted according to their respective value-added for 1959. The weights, which represent factor payments in the form of wages, incomes in kind, interest, and rent, and depreciation charges, have been derived in a separate publication by the author.[40] The separate sector indexes have been obtained as follows:

Industry.—See table 2 in contribution of James Noren.

As distinguished from estimates for earlier contributions, production of military products has been included.

Construction.—Indexes in 1955 prices of state and cooperative (p 44) and private housing (pp 188–189) from Tsentral'noe Statisticheskoe Upravlenie, *Kapital'noe Stroitel'stvo v SSSR*, 1961 for data through 1960. 1961–1964 estimates from *Narodnoe khoziaisvto SSSR v 1964 godu*, pp. 511–512.

Agriculture.—See table 1 in contribution of Douglas Diamond.

Transportation.—Norman M. Kaplan, *Soviet Transport and Communications Output Indexes*, 1928–62, Rand Corporation, (TM–4264–PR), 1964, p. 55 and supplement of Nov 1965, p 7. 1964 output obtained by adjusting 1964 link relative for volume of freight (Table 1 in contribution of Holland Hunter) by 1955–63 relationship between index of freight volume and Kaplan's computed freight output index.

Communications.—Norman Kaplan, *op. cit.*, pp 7 and 55. 1964 index obtained by adjusting 1964 link relative for employment (Table A–1 in contribution of Murray Feshbach) by 1955–62 relationship between index of employment and Kaplan's index of employment and revenue.

Commerce.—Index moved by trend of employment in trade, procurement and supply (Table A–1 in contribution of Murray Feshbach) times an assumed increase in productivity per worker of 0.7 percent per year. This increase in output per employee was computed for services sectors in the United States for the period 1929–61 (Victor Fuchs, *Productivity Trends in the Goods and Services Sectors*, 1929–61, National Bureau of Economic Research, 1964, p. 13). In lieu of indigenous information this trend is also presumed to apply to non-commodity sectors in the Soviet economy.

Services—The index for this sector is comprised of the weighted indexes for the component sub-sectors: Defense (military personnel costs), education, health, public administration, science, and housing and communal services. These six sub-sectors comprised over 97 percent of total outlays for services in 1959 (Stanley H. Cohn, *Derivation of 1959 Value-added Weights for Originating Sectors of Soviet Gross National Product*, Research Analysis Corporation, TP–210, 1966, pp. 15, 17). The weights for each sub-sector are the summed cost elements of wages and supplement ,sinterest, depreciation charges. The wage bills are 1959 average annual wages per employee (*Narodnoe Khoziaistvo, 1964*, p 555) times 1959 employment in the sub-sector (*Ibid.*, p 547). The other cost estimates are derived from notional distribution of component costs for services obtained from Stanley Cohn, *op. cit.*

The indexes for the sub-sectors, except for housing and communal services, are based on employment trends, adjusted for the assumed 0.7 percent annual productivity increase. The defense manpower estimates are obtained from *Dimensions of Soviet Economic Power*, p 43, the column on million man-years and from Institute for Strategic Studies, *Military* Balance, 1962–62, 1963–64, 1964–65, London. The employment indexes for the other sub-sectors are obtained from the above cited official source. The housing index is based on estimates of total living space, derived from the sources cited in Table 8 in contribution of David Bronson and Barbara Severin.

Appendix B. Derivation of 1964 End Use Distribution of Soviet GNP

The procedure for deriving distribution of Soviet gross national produce in 1964 involves three separate calculations: (1) derivation of 1955 distribution of GNP, (2) calculation of indexes of trends in the component end uses in either

[40] Stanley H. Cohn, Derivation of 1959 Value-added Weights for Originating Sectors of Soviet Gross National Product, Research Analysis Corporation (TP–210, 1966, p. 20.

constant or current prices, (3) computation of price deflators for those end-uses whose trends are in constant prices.

TABLE B–1.—*1964 distribution of Soviet GNP*

[Billions of rubles]

End use	1955 distribution	Index, 1964 (1955=100)	Deflator, 1964 (1955=100)	1964 distribution [1]	1964 proportion (percent)
Private consumption	48.7	149.1	107.2	77.8	46.5
Public consumption	7.9	165.2	120.5	15.7	9.4
Fixed investment	23.1	231.1	90.7	48.4	28.9
Defense	12.5	151.3	(2)	18.9	11.3
Inventories	1.2	217.9	(2)	2.6	1.6
Government administration [3]	2.8	113.9	118.7	3.8	2.3
GNP	96.1			167.2	100.0

[1] 1964 distribution equal to 1955 distribution times physical index times deflator.
[2] Not applicable.
[3] Combined with public consumption in table 4.

SOURCES AND METHODOLOGY

1955 distribution of GNP by use

The 1955 estimates are those computed in adjusted prices by Morris Bornstein and associates in *Soviet National Accounts for 1955*, Center for Russian Studies, University of Michigan, 1961, pp 71–76.

End use indexes, 1955–1964

Private and public consumption—adapted from Table 8 in contribution of David Bronson and Barbara Severin.

Fixed investment—*Narodnoe khoziaistvo SSSR v 1964 godu*, p 511.

Kapital'noe stroitel'stvo v SSSR, pp 40, 188, 189.

Defense—The 1955–62 portion of the defense index is obtained from Abraham Becker, *Soviet Military Outlays since 1955*, Rand Corporation (RM–3883–PR), p 36. My estimates include Becker's explicit defense budgetary estimates plus his science expenditures, plus the mid-points of his low and high residual expenditure alternatives. The 1963 and 1964 estimates of increases of 8 and 4 percent, respectively, are based on analysis of available official budgetary data.

Inventories—Tsentral'noe Statisticheskoe Upravlenie, *Narodnoe Khoziaistvo SSSR v 1964 godu*, 1965, p 751. The 1955 values have been interpolated from published 1950 and 1958 values. The estimates have been limited to physical assets, excluding monetary working capital.

Government administration—Based upon employment trends in administration (table A–1 in contribution of Murray Feshbach), adjusted for an assumed 0.7 percent annual productivity increase.

Price deflators

Since available price indexes are available only for inputs into the end uses of GNP or for components of expenditure, rather than for the end uses themselves, the indexes are based upon weighted price indexes for indicator inputs or outputs comprising each end use. In all cases the indicators have been weighted by their 1959 proportions.

Private consumption—Price indexes for the expenditure components of goods sold in state retail stores, collective farm market sales, and private expenditures for services are weighted expenditures for these purposes as estimated by Abraham Becker in *Soviet National Income and Product, 1958–62, Part I*, Rand Corporation (RM–4394–PR), p 9. The weight for income in kind is based on the estimate in Stanley H. Cohn, *Derviation of 1959 Value-added Weights for Originating Sectors of Soviet Gross National Product*, Research Analysis Corporation (TP–210), p 24. The weights are, in terms of billions of rubles, 64.7 for state retail store sales, 4.2 for collective farm market sales, 9.7 for services, and 14.0 for income in kind.

The price indexes for goods sold in retail outlets is the official index obtained from *Narodoe khoziaistvo SSSR v 1960 godu*, p. 717 and from the 1964 edition of the same volume, p. 649. The index for collective farm market sales is obtained

from "Soretskaia Torgovlia," 1964, p. 266. The price index for income in kind is a weighted average reflecting the proportionate sizes of state retail trade and collective farm market sales in private consumption as a whole.

The price index for services is weighted 3 to 1 by the price indexes for wages and goods based on the cost structures for the most important private and public services—education, health, and culture—in Akademiia Nauk SSSR, *Mezhotraslevoi balans proizvodstva i raspredeleniia produktsii ekonomicheskogo raiona*, 1964, p 199. The wage index is the official one for workers and employees obtained from the 1964 statistical yearbook, p 555. The index for goods is the official one for all industrial production without turnover tax obtained from the same volume, p 154.

Public consumption.—The index computed for private services is also used for public consumption, as both types of activities resemble one another in labor intensity.

Fixed investment.—The two basic expenditure components of construction and machinery and equipment are weighted by their 1959 values (Joint Economic Committee, *Current Economic Indicators for the USSR*, Table IV–1). The construction price index is the official one found in the 1964 statistical handbook, p 540. The price index for machinery and equipment is the official index without turnover tax for machine building and metalworking from the same source, p 154.

Defense.—Since the physical index is in current terms, no deflator is required.

Inventories.—The current ruble nature of the computed trend precludes the need for a price deflator.

Government administration.—The administrative category is weighted 2 to 1 between personnel and materials expenditures (G. Margelov, *Planirovanie i finansirovanie raskhodov na upravlenie*, 1962, p 11). The price index for the personnel component is the aforementioned wages index and the deflator for the goods portion is the aforementioned index for all industrial output.

Deflator for gross national product

In order to obtain a deflator for all of GNP from the third column of the foregoing table, it is necessary to derive deflators for defense and inventories. The defense estimate of 16.4 billion rubles in 1959 obtained from Abraham Becker, *op. cit.*, is divided into three components of personnel wages, personnel subsistence, and non-personnel expenditures. The estimate of 2.5 billion rubles for wages and 1.4 billion for subsistence are obtained from Stanley Cohn, *op. cit.*, p 15; the non-personnel estimate of 12.5 billion emerging as a residual. The wages component is moved by the wages index, the subsistence component by the price index (excluding turnover tax) by the official index of light food industry (*Narodnoe khoziaistvo v 1964 godu*, p 154), and the non-personnel component by the aforementioned index for machinery and metalworking production. The resulting deflator for defense (1955=100) is 91.9.

The inventories component is moved by the previously derived price index for all industrial production, as the bulk of inventories consist of industrial goods. If the 1964 estimates for defense and inventories are deflated by these indexes, the value of GNP for 1964 in 1955 prices is 162.8 billion rubles. Comparing this estimate with the value in 1964 of 167.2 billion rubles yields a price index of 103.0.

Appendix C—Derivation of Estimate of Annual Working Hours

Official data on working hours is limited to information on industrial hours and scattered data on hours in agriculture. In the overall estimate I have assumed that changes in working hours in industry are also applicable to all non-agricultural activities. While no comparable hours trends have been provided for non-industrial sectors, in 1964 the average work week for all workers and employees was slightly less than for industrial workers.[50] The same source also alludes to the reduction in the work day for educational and medical personnel.

Non-agricultural working hours.—According to Bureau of Census estimates, the annual work year in industry was 2,210.4 hours in 1950, 2,063.6 in 1958, and 1,833.3 in 1963. When multiplied by the estimated employment in these sectors for the respective years, a man-hours trend is derived.

[50] Narodnoe khoziaistvo SSSR v 1964 godu, p. 590.

	Nonagricultural employment (millions) [1]	Nonagricultural work year (hours) [2]	Nonagricultural man-hours (billions) [3]
Year—			
1950	41.478	2,210.4	91.7
1958	53.299	2,063.6	111.0
1964	67.590	1,833.3	123.9

[1] Civilian employment from table 5 in contribution of Murray Feshbach. Armed forces estimates from Institute for Strategic Studies, *Military Balance*, 1962–63, 1963–64, and 1964–65, London.
[2] Joint Economic Committee, *Current Indicators for the U.S.S.R.*, 1965, table VI–6. This work week was unchanged in 1964.
[3] Left column times center column.

Agricultural and Total Working Hours.—Estimates of agricultural working hours are derived from the contribution of Douglas Diamond to this compendium. When they are added to the foregoing estimates of nonagricultural hours, an economy-wide estimate is obtained.

	Agricultural man-hours (billions) [1]	Total man-hours (billions) [2]	Average annual man-hours [3]
Year—			
1950	85.0	176.6	2,140.9
1958	83.5	194.5	2,052.4
1964	77.5	201.4	1,890.1

[1] Adapted from table 14 in contribution of Douglas Diamond.
[2] Agricultural plus nonagricultural man-hours.
[3] Total man-hours divided by total employment.

APPENDIX D. DERIVATION OF INDEX OF GROWTH OF EDUCATIONAL STOCK

The index of growth of educational stock was originally developed by Nicholas DeWitt.[51] Among other periods DeWitt estimated the value of educational stock in the Soviet labor force on December 31, 1950 and January 1, 1959. His estimates have been used for these two years. My estimate of educational stock on January 1, 1965 follows DeWitt's technique. Basically the procedure involves valuation of the varying levels of educational attainment of the employed labor force. A particular level of attainment is capitalized as the total cost expended for education, including incomes foregone by the student. Costs are in terms of 1955 prices, the same as those used to value physical investment. The index is, therefore, a function of changes in the structure of educational attainment, reflecting both educational policy and demographic factors.

For illustrative purposes I have shown only the computation of the January 1, 1965 educational stock estimate (Table D–2). Since DeWitt's procedure has been followed, his estimates for the earlier years will be sourced to his original computations, rather than presented in their detailed derivations.

TABLE D–1.—*Trends in Soviet educational stock*

	Educational stock (billion rubles)	Increase in educational stock (annual average)	Increase in educational stock per employee (annual average) [1]
Year—			
1950	[2] 48.3		
1958	[2] 83.7	7.1	5.2
1964	[3] 110.2	4.7	2.6

[1] Index of educational stock ÷ index of employment (table 3).
[2] Nicholas DeWitt, "Costs and Returns in Education in the U.S.S.R., 1962" (an unpublished dissertation of Harvard University), p. 273.
[3] See table D–2.

[51] Nicholas DeWitt, "Costs and Returns in Education in the U.S.S.R., 1962" (an unpublished dissertation of Harvard University).

TABLE D–2.—*Estimate of Soviet educational stock, Jan. 1, 1965*

Educational attainment	Population 15 years and older [1] (millions)	Employment		Educational stock	
		Percent of population [2]	Millions	Per person [3] (rubles)	Labor force [4] (million rubles)
Illiterate	3.5	[5]	[5]	[5]	[5]
Elementary (6 years or less)	78.7	65.0	51.2	139.6	7.15
Partial secondary (7 to 9 years)	45.7	73.8	33.7	952.3	32.09
Complete secondary (10 years)	12.0	74.0	8.8	1,659.6	14.60
Specialized secondary	10.6	80.7	8.6	2,407.6	20.71
Partial higher	2.4	80.8	1.9	3,859.6	7.33
Complete higher	5.6	80.7	4.5	6,300.1	28.35
Total	158.4		108.3		110.23

[1] The official distribution of the educational attainment, adult population, 15 years and older (Narodnoe khoziaistvo v 1964 godu, p. 33), covers the 76.3 million persons who have finished or partially completed higher and secondary education. Of the remaining 82.2 million out of a total population of 15 years and older of 158.5 million (Current Economic Indicators for the U.S.S.R., 1965, p. 38), 3.5 million are estimated to be illiterates, leaving 78.7 million with 6 years of education or less. The estimate of illiterates represents a decline from the 1959 census enumeration of 4.183 million.

[2] The proportion of the population in each attainment group engaged in gainful employment is assumed to be unchanged from 1959 census estimates (DeWitt, op. cit., p. 135).

[3] DeWitt, op. cit., table M–3 stub, p. 273.

[4] (3) × (4).

[5] Negligible.

APPENDIX E. DERIVATION OF INDEXES OF END USES OF GNP, 1950–58 AND 1958–64

The procedures described in Appendix B for the derivation of end use indexes for the period 1955–1964 have also been used to obtain indexes in constant prices for the years 1950–58 and 1958–64. A modification has been introduced for derivation of the index of defense expenditures.

Private and public consumption—Adapted from Joint Economic Committee, *Current Economic Indicators for the U.S.S.R.*, 1965, Tables II–1, VIII–1 and VIII–2 and Table 8 in contribution of David Bronson and Barbara Severin.

Productive fixed investment and housing—*Narodnoe khoziaistvo SSSR v 1964 godu*, pp. 511 and 514 and *Kapital'noe stroitel'stvo v SSSR*, pp. 40, 188, and 189.

Defense—The base year (1959) division of defense among personnel pay, personnel subsistence, and non-personnel components has been previously derived in Appendix B. The wage and subsistence components are moved to 1950 and 1958 by estimates of troop strength obtained from Joint Economic Committee, *Dimensions of Soviet Economic Power*, 1962, p. 43. The 1964 armed forces strength is obtained from Institute of Strategic Studies, *Military Balance, 1964–65*. The computed wage and subsistence estimates for these years are converted to current prices by respective deflators for wages (*Nar. khoz.* 1964, p. 555) and for wholesale prices of light and food industry (*Ibid.*, p. 154). The current prices estimates for these two categories are then subtracted from estimates of total defense expenditures (1950 *Dimensions of Soviet Economic Power*, p. 37 and 1958 and 1964 see Appendix B) to obtain current value estimates of non-personnel expenditures as residuals. The current value estimates for non-personnel expenditures are converted to constant 1959 prices by the wholesale price index for machinery (*Nar. khoz.* 1964, p. 154). The sum of the three components comprises the constant price time series for total defense expenditures.

COMPARATIVE PROGRESS IN TECHNOLOGY, PRODUCTIVITY, AND ECONOMIC EFFICIENCY: U.S.S.R. VERSUS U.S.A.

BY

MICHAEL BORETSKY

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COMPARATIVE PROGRESS IN TECHNOLOGY, PRODUCTIVITY, AND ECONOMIC EFFICIENCY: U.S.S.R. VERSUS U.S.A.

INTRODUCTION*

Ever since Ricardo,[1] economists have been interested in technological change as a source of growth in productivity and, hence, the amount of output an economy can produce in excess of growth of its resources. The intensity of this interest, however, has been highly intermittent.

Thus far, there seem to have been two peaks in the economic profession's interest in technological change. The first culminated in Schumpeter's familiar theory of economic change, developed more than half a century ago.[2] The current peak, started by Robert M. Solow some 9 years ago,[3] has produced studies on an almost weekly basis.[4]

Although analytically the studies of technological change made since 1957 have essentially produced only empirical quantification of the Schumpeterian aggregate concept of innovation (in Schumpeter's view, the sole cause of economic change) and some data on economic effects of specific innovations, and all this, with only one exception[5] on a noncomparative basis, their reemphasis of the subject matter has had a profound influence on actions of governments all over the world and also on actions of international governmental organizations. Increasingly, governments and international governmental organizations are formulating policies and programs aimed at making maximal use of the potentialities of technological progress. To that end, most of the economically developed nations seem by now to have made more or less elaborate official or semiofficial institutional arrangements for increasing the flow of new know-how and for speeding its effec-

*The theoretical framework for this study was developed and most of the necessary research done at the Brookings Institution in 1965, during my Federal executive fellowship study of data and sources of information on technological change in the United States. While at Brookings I profited from conversations on the subject with numerous members of its staff, particularly Edward F. Denison, Lawrence B. Krause, Holland Hunter, Rashi Fein, Joseph A. Pechman, and William M. Capron, as well as my FEF colleagues, Sidney A. Jaffe and Richard Hellman. I am also indebted to Paul W. McGann, of the Department of Commerce, and James W. Knowles, of the Joint Economic Committee, for critical comments on an earlier draft. The responsibility for the views expressed here, however, is solely my own. These views do not purport to represent the views of the Brookings Institution or the U.S. Department of Commerce, my present employer.

[1] For Ricardo's references to technological change see P. Scaffa (ed.), "Works and Correspondence of David Ricardo," Cambridge, England: Cambridge University Press, 1951–55, vol. 1. pp. 137–144.

[2] Schumpeter spent his professional life developing his theory of economic change, but its essential features were set forth in the Theorie der wirtschaftlichen Etwicklung, published in 1911. See Richard V. Clemence and Francis S. Doody, "The Schumpeterian System," Cambridge, Mass., Addison-Wesley Press, Inc., 1950, p. 1.

[3] In his "Technical Change and Aggregate Production Function," the Review of Economics and Statistics, vol. XXXIX, August 1957, pp. 312–320.

[4] A bibliography of most important studies dealing with subject matter that appeared in the United States through the middle of 1964 may be found in Richard R. Nelson's "Aggregate Production Functions and Medium-Range Growth Projections," the American Economic Review, vol. LIV, September 1964, pp. 605–606.

[5] See Robert M. Solow, "Capital Theory and the Rate of Return," North-Holland Publishing Co., Amsterdam, 1963.

tive use. As a result, the last 10 years or so have been marked by a remarkably rapid growth of research and development activities and probably by equally rapid growth of the institutions whose objective is to stimulate rapid introduction and further diffusion of new technology. These latter have been organized as productivity councils, modernization committees, science and/or technology ministries or departments, technical information centers, and the like. Following the lead of the economically developed nations, the United Nations has started looking for ways to tap new technology for speeding development of the economically underdeveloped nations. The most notable U.N. steps undertaken in this direction have been the Conference on the Application of Science and Technology for the Benefit of Developing Areas, held in Geneva in October of 1963, and the establishment of a separate Technology Division in its Committee for Industrial Development, which studies ways of speeding present methods of transferring and adapting new technology in the underdeveloped economies.

The objective of this paper is to add to the available studies of technological progress both methodologically and informationally. The focus is on comparative progress in technology, productivity, and economic efficiency in the U.S.S.R. and the United States between 1939–40 and 1962.

The methodological contribution of the study lies in its approach to the subject matter. The essence of this approach might briefly be described as defining and analyzing the progress in technology and the progress in factor productivity as separate concepts with overall conclusions drawn on the basis of both analyses. The informational contribution of the study, in turn, lies in the fact that it systematically analyzes the performance of the two most important ideologically rival economies in the world over a long enough period for meaningful generalizations. In fact, the time covered represents most of the mature lifespan of the Soviet economic system as we presently know it.

Inasmuch as technological progress is a major and, to a large extent, controllable factor of productivity growth, this study might obviously be considered as an analysis of the extent to which the two economic systems have made use of potentialities for productivity growth and, hence, as an analysis of the efficiency or objective merits of the two economic systems.

Needless to say, because of the extreme complexity of the subject matter and the novelty of the approach, the study must be considered as exploratory. Consequently, the various measures presented and conclusions drawn should be viewed as approximations rather than in any sense precise measures or facts. I believe, however, that these approximations will illuminate this extremely important but unexplored area of inquiry and, therefore, will prove interesting and instructive to both the professional economists and policymakers both in the United States and the U.S.S.R. and also in other countries, particularly the underdeveloped nations.

The study consists of seven parts and three appendixes.

Part I summarizes briefly the methodological approaches currently used in studies of technological change and sets forth the approach followed in this study.

Part II gives a summary of major findings.

Part III is devoted to a detailed comparative analysis of technological progress as defined in part I. The analysis is in terms of specific indicators of technological change as well as the aggregate change.

Part IV sets forth the comparisons of factor productivity growth distinguishing between labor productivity (output per unit of labor input), capital productivity (output per unit of fixed business capital input), and total factor productivity (output per unit of aggregated factor input).

Part V analyzes the implications of the findings of parts III and IV with primary focus upon the consistency of the findings arrived at in the comparisons of technological progress and factor productivity, the differential utilization of potentialities for productivity growth in the two economies, an additional comparison of factor productivity growth in the U.S.S.R., the United States, and major West European market economies and therefrom arising implications as to the efficiency capabilities of the Soviet economic system relative to market economies, the cost of the Soviet system's comparative inefficiency to the economy, and a few other purely analytical implications.

Part VI, amplifying the analysis set forth in parts III to V, discusses some of the major sources of inefficiency in the Soviet economy.

Part VII contains a brief discussion on the developments that took place between 1962 and 1964/5 and on future prospects for progress in technology and productivity in the U.S.S.R. and the United States.

The appendixes contain a brief summary of the Soviet studies of economic effectiveness of technological change (app. A), estimates of weights used in the aggregation of comparative individual indicators of technological change into an overall average (app. B), and the data underlying the factor productivity analysis (app. C).

I. Methodology

As noted in the introduction, for the last 10 years or so economists have shown a very keen interest in technological change with the result that new studies of the subject matter are now an almost weekly occurrence. Before I proceed with the outline of the methodology followed in the present study, it seems, therefore, appropriate to give a broad sketch of how the studies done thus far have dealt with the matter. Needless to say, such a short sketch runs the risk of oversimplification, but I hope it will help to give a better understanding of the advantages and disadvantages of what I propose.

CURRENT APPROACHES TO STUDY OF TECHNOLOGICAL CHANGE

The way I see it the approaches used in most, if not all, of the recent studies of technological change may be classified into three groups: Studies following the production function approach, Denison's approach, and case studies of technological change.

The production function approach

The most influential of the three current ways of analyzing technological change is the production function approach, initiated by

Robert M. Solow in 1957.[6] In this approach, technological (or technical) change is defined by the extent to which a Cobb-Douglas aggregate production function of the economy, or some part of it, shifts over time. Algebraically this concept is defined in discrete terms as:

$$\frac{\Delta A}{A} = \frac{\Delta(Q/L)}{Q/L} - b\frac{\Delta(K/L)}{K/L} \tag{1}$$

where A = level of technology,
Q = aggregate output,
L = labor input,
K = capital input,
b = share (proportion) of capital income in the aggregate output.

Technological change in this approach, measured by $\Delta A/A$, is thus equal to that part of the annual percentage increase in output per head or man-hour that cannot be explained by the increase in capital input per head or man-hour.

If calculated without reference to output per head or man-hour, definition (1) of this approach becomes

$$\frac{\Delta A}{A} = \frac{\Delta Q}{Q} - \left(1-b\right)\frac{\Delta L}{L} - \frac{b\Delta K}{K} \tag{2}$$

Verbalized, definition (2) means that technological change is equal to that part of the annual percentage increase in aggregate output that is in excess of increases in (unchanged) value of labor and capital inputs.

Up to 1962, technical change defined in this manner had been assumed to be neutral; that is, not attributable to any particular cause. In 1962, however, Solow introduced the important concept of technological change as a function of the addition of newly produced capital goods to the economy's stock ("embodiment" model of technological change).[7] Under this assumption, growth in output in excess of growth of physical inputs is possible only if old capital is replaced by capital of newer vintage and/or new capital is added to the stock.

As of now, however, the question whether technological change is "embodied" or "disembodied" is still very much in debate.[8]

Most of the studies of technological change which use the production function approach focus on the economy as a whole. Benton F. Massel made a bold effort to use it also for a study of specific manufacturing industries.[9]

It should be clear from the preceding outline that the concept of "technical" change as defined in the production function approach means the contribution of "technical" change to growth in output and covers not only the contribution of technical change in the conventional

[6] Op. cit.
[7] Robert M. Solow, "Technical Progress, Capital Formation, and Economic Growth," the American Economic Review, proceedings, vol. LII, May 1962, pp. 76–86.
[8] See, e.g., Kenneth J. Arrow, "The Economic Implications of Learning by Doing," the Review of Economic Studies, vol. XXIX, June 1962, pp. 153–173, and Michael D. McCarthy, "Embodied and Disembodied Technical Progress in the Constant Elasticity of Substitution Production Function," the Review of Economics and Statistics, vol. XLVII, February 1965, pp. 71–75.
[9] Benton F. Massel, "Capital Formation and Technological Change in United States Manufacturing," the Review of Economics and Statistics, vol. XLII, May 1960, pp. 182–188.

(narrow) sense (representing the introduction or further diffusion of cost-reducing innovations) but also the contribution of improvements in management, increases in skill level of manpower, improvements in resource allocation, and all other factors that affect overall economic efficiency. In short, the concept of "technological change" in the production function approach represents the "residual" or "catchall" rather than technological change in a narrow sense.

The production function approach has been criticized on grounds that it fails to define technological change in a narrow sense and that none of the information it provides is really new because the estimates of "technological change" which it yields are virtually identical with those obtainable by means of "total factor productivity" approach defined earlier by Schmookler, Abramovitz and, especially, Kendrick.[10] While these reservations are correct, they are not serious. The way I see it the main shortcoming of the production function approach for study of technological change is that it provides extremely narrow information and within the framework of this approach there is no easy way, if any, to expand it.

Denison's approach

Denison's work [11] does not address itself directly to the study of technological change, but is is pertinent to it. As in production function approach studies, Denison defines the contribution of technological change to growth in output as a residual, but it is a different residual both in terms of concept and in terms of size.

Starting with an average percentage growth in aggregate output (real national product) for a period, Denison subtracts from it the contributions made by growth of labor adjusted for quality change (on account of education, increase in experience, changes in age and sex composition, and so forth, land and capital, which leaves him with the first residual, designated as percentage "increase in output per unit of input." The percentage points contribution of each of the three factors to the overall growth in output is derived from the percentage growth of the input multiplied by its share in national income.

Using various criteria, Denison's first residual, that is, percentage increase in output per unit of input, is further broken down into contributions of changes in restrictions against optimum use of resources, changes in waste of labor in agriculture, changes in industry shift from agriculture, changes in lag of application of knowledge and changes in economies of scale. What is left, the second residual, is designated as the contribution of "advance of knowledge."

It seems reasonable to assume that the contribution of "advance of knowledge" is what Denison considers to be the contribution of technological change in the narrow sense and of some other minor factors that he did not estimate.

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[10] Reference is made to Jacob Schmookler, "The Changing Efficiency of the American Economy, 1896–1938." The Review of Economics and Statistics, vol. XXXIX, August 1952, pp. 214–231; Moses Abramovitz, "Resource and Output Trends in the United States Since 1870," the American Economic Review, proceedings vol. XLVI, May 1956, pp. 5–23; John W. Kendrick, "Productivity Trends: Capital and Labor," the Review of Economics and Statistics, vol. XXXVIII, August 1956, pp. 248–257; and "Productivity Trends in the United States," NBER, Princeton University Press, Princeton, 1961. Michael D. McCarthy, in his study of embodied and disembodied technological change by means of production function approach reference to which was made in note 8 above, freely uses Kendrick's estimates of "total factor productivity" in place of "technical change" estimates.

[11] Edward F. Denison, "The Sources of Economic Growth in the United States and the Alternatives Before Us," supplementary paper No. 13, Committee for Economic Development, New York, 1962.

Two reservations come to mind with respect to this method. First, most of the factors defined by Denison as contributors to the "increase in output per unit of input" (particularly industry shift from agriculture, reduced waste of labor in agriculture, and economies of scale) clearly involve technological change in a narrow sense. The second and, perhaps, more important reservation is that most of the contributions of advances in skill level of labor are not independent, but presuppose technological change.

The case studies

The group of case studies of technological change includes numerous studies made by the Bureau of Labor Statistics Division of Technological Studies,[12] studies by James F. Bright,[13] some of the studies by Edwin Mansfield,[14] a recent study by Samuel Hollander,[15] my own earlier study,[16] and many others of similar type. Most of the studies of technological change produced in the U.S.S.R., to which numerous references will be found later in this study, belong also to this group. The case studies vary immensely in scope and detail of information. In scope, they range from a study of a single innovation, such as the BLS study of a modernized petroleum refinery [17] to a study of technological trends of a major sector of the economy, such as my own study, mentioned above,[18] of technological innovations in the process of diffusion in machine building industries in the United States and the U.S.S.R. In terms of detail of the information, these studies encompass both a comprehensive evaluation of economic consequences of technological changes in certain manufacturing plants of a company over a span of some 30 years, as given in Hollander's study, and also broad qualitative generalizations about sociological implications of "computerization" of the economy.

The value of the case studies is that they provide a substantial amount of raw information about the technological change in the areas studied and, thus, furnish some hypotheses as to what technological change does to the economy. As these studies are being done in a highly uncoordinated manner, however, they permit no reliable generalizations as to the rate and economic implications of technological change in the economy as a whole and, hence, cannot serve as a basis for policy.

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[12] A selected annotated bibliography of BLS studies as well as of many others published through 1961 may be found in "Implications of Automation and Other Technological Developments," Bulletin No. 1319, U.S. Department of Labor, 1962; and of subsequent studies in annual reports of the Secretary of Labor on manpower research and training (MDTA).

[13] E.g., Automation and Management, Boston, Harvard University, Graduate School of Business Administration, 1958; "Does Automation Raise Skill Requirements?" Harvard Business Review, July-August 1958, pp. 85–98; and "Progress and Payoff in Industrial Automation." Dun's Review of Modern Industry, January 1960, pp. 44–46.

[14] E.g., "Entry, Gibrat's Law, Innovation, and the Growth of Firms," The American Economic Review, LII (December 1962), pp. 1023–1051; and "The Speed of Response of Firms to New Techniques," Quarterly Journal of Economics, LXXVII (May 1963), pp. 290–311.

[15] The Sources of Increased Efficiency: A Study of DuPont Rayon Plants, Cambridge, Mass., The M.I.T. Press, 1965.

[16] "The Soviet Challenge to U.S. Machine-Building, a Study in Production and Technological Policy" in Joint Economic Committee of U.S. Congress "Dimensions of Soviet Economic Power," December 1962, pp. 69–143 (published in 1963 by the U.S. Department of Commerce as a separate publication).

[17] BLS Report No. 120.

[18] Op. cit. (note 16), app. D.

THE APPROACH IMPLICIT IN THE PRESENT STUDY

In broad terms the approach followed in the present study might be described as defining and analyzing technological progress and progress in factor productivity as separate concepts with conclusions about efficiency and other economic phenomena drawn on the basis of both analyses. Its essence lies in the "deresidualization" of the concept of technological progress.

The concept of technological progress of an economy in this approach is defined as a sum of all technological innovations introduced and/or further diffused in the economy over a period of time, which either permit production of products or services with a lower cost than before or permit production of products or services impossible or impractical to produce before. The statistical analog of this concept is conceived as an index derived from direct indicators of specific (technological) factor augmenting innovations introduced and/or further diffused in the economy over a period of time weighted with relative total cost savings (factor savings to the economy) per unit increase in the use of the respective innovations. This definition obviously assumes that technological progress is "embodied" in new capital goods, new energy sources, and new industrial materials.

The progress in factor productivity, however, is defined in the conventional way, that is, as growth in aggregate output per unit of input, with distinction made between progress in total factor productivity, or output per unit of aggregated input (usually inputs of labor and capital weighted with respective shares in national income); labor productivity, or output per unit of labor input; and capital productivity, or output per unit of capital input.

The concept of efficiency of an economy, finally, is also defined more or less in the conventional way; namely, as the economy's performance with respect to its optimal potentialities or some other standard, such as performance of another economy having the same potentialities. The progress in efficiency is defined analogously; namely, as the rapidity with which the performance of the economy moves to its optimum or relative to the improvement of another economy having the same potentialities. This definition implies that, e.g., a comparison of two countries' performance in terms of total factor productivity growth does not permit judgments with respect to progress in efficiency unless the countries compared have had equal potentialities for the productivity growth or the judgments account for the differences in the potentialities.

The principal novelty in this approach, and the only aspect in need of amplification, is the index of technological progress. There is no need to discuss here the concepts of factor productivity or efficiency which are conceived as integral parts of the approach pursued in this study. As noted earlier, the concept of factor productivity has been described by Kendrick, Denison, and others and the conclusions about efficiency are drawn inferentially. It is essential, however, that the estimating procedure of the index of technological progress, its con-

ceptual meaning, especially in relation to the concept of total factor productivity, the practical possibilities of constructing such an index, and its analytical advantages and limitations be thoroughly understood. I shall discuss these points with reference to the hypothetical estimating illustration below.

For purposes of this illustration assume the following:

The economy's technological progress in 1950–62 consisted only of two innovations: expansion in the use of plastics and expansion in the use of manmade fibers; each additional ton of plastics used was saving the economy $5,000 worth of resources which were being converted to production of other goods of equal value, and each additional ton of manmade fibers was saving $3,000 worth of resources. The statistics on the use of these two innovations in the economy were as follows:

Innovation	1950	1962
Use of plastics, tons	100	200
Use of man-made fibers, tons	100	500

Procedure of estimating the index

In calculating the index of technological progress based on these data, each of the two innocations is assigned a weight in accordance with the relative magnitude of total cost savings to the economy per unit increase in the use of the two innovations. The total cost saving to the economy per unit increase of the two innovations is $8,000. Since a ton of plastics saves the economy $5,000, use of plastics is assigned the weight of $\frac{5}{8}$; analogously, use of manmade fibers gets the weight of $\frac{3}{8}$. We assume that these proportions remain constant over some time. In short, the estimating procedure follows the familiar fixed weight (Laspeyres) index number formula, the same as used in the construction of the FRB index of industrial porduction, price indexes, and most other economic indicators. The use of fixed weights in this index is predicated upon the assumption that although the economic impact of individual innovations on the economy tends to diminish over time this tendency is counteracted by subsequent improvements in the innocations and, hence, there is a relative stability of their effectiveness over long stretches of time. The precedure permits occassional substitutions of one component for another, additions of new components, and periodic changes of weights, as is being done in other applications.

The index of technological progress consisting of the two innovations given in the example would thus be (1950=100):

	1950	1962
Use of plastics	$\frac{5}{8}$ (100) = 62.5	$\frac{5}{8}$ (200) = 125.0
Use of man-made fibers	$\frac{3}{8}$ (100) = 37.5	$\frac{3}{8}$ (500) = 187.5
Total (index)	100.0	312.5

The meaning of the index of technological progress

In the example, the index obviously represents an index of total cost savings to the economy resulting from the defined technological change. In the conditions of full employment, or in calculations in which adjustments are made for underemployment of resources, the index might also be interpreted as an index of factor augmentation. With reference to total factor productivity (or production function approaches) this index might be said to be conceptionally equivalent to that portion of the index of output per unit of total factor input (or index of "residual" increments) that is caused by or is dependent on technological change in a conventional sense of the term.

The dependence of growth in output per unit of total factor input on technological change is considered, however, to be greater than is commonly assumed by students of productivity. Students of productivity usually assume that, in addition to technological change proper, output per unit of total factor input is also influenced by improvements in average skill level of manpower acquired through education, "learning by doing" and other factors, improvements in management, interindustry shifts of factors of production, economies of scale, changes in conditions of demand, and other lesser factors. The importance of all factors other than technology can hardly be disputed. I assume, however, that in most cases their contribution to the growth in output per unit of total factor input depends on technological change proper. This is certainly true in cases of increasing skill levels of manpower (which by and large could not be fully utilized without counterpart improvements in technology), interindustry shifts of factors of production, and economies of scale, and to a large extent in the case of improvements in management (which is dependent on timely data availability and communications). The only factor that seems to be independent of technological change proper is change in the conditions of market demand, which affects the degree to which productive capacity is being utilized. On the whole, I assume that in the conditions of ideal data availability for construction of both indexes, the changes in the index of technological progress would roughly be equal to those in the index of output per unit of total factor input between times of optimum or full capacity utilization and between the times of equal degrees of capacity utilization, but differ between the times of different capacity utilization.

Practical possibilities of constructing the index of technological progress

Ideally the construction of the index of technological progress of an economy for any time period as defined above presupposes: information as to what were the specific technological innovations that the economy introduced or further diffused over the period, the existence of statistical data permitting quantitative determination of the extent of the introduction or diffusion, and data on the economic effectiveness that would permit estimation of a meaningful set of weights and at least a rough approximation of the contribution of the aggregate of the innovations to the growth in output per unit of aggregated input.

An empirical study of any economy could hardly aim at an index of technological progress based on all innovations. The reasons for this are not only data limitations, but also the cost. Nevertheless, my research indicates that an index of technological progress based on data for introduction and diffusion of key innovations is feasible in terms of actual and/or potential data availability and cost for both the United States and almost all other developed countries.

By the term "key innovations" I mean those innovations that are important in themselves and the trend in their use might be presumed to represent the trend of a host of other innovations not directly included in the index. The use of fertilizers per acre of cropland in agriculture, for example, might be considered as a key indicator of technological change because the use of fertilizers is important in itself and most probably reflects the general trend in the use of chemicals in agriculture; the consumption of electric energy per production worker in industry is another key indicator because of the representation of the use of "electrotechnology" as well as a host of other small innovations in process equipment, increases in motive power, and the like.

The use of the index of technological progress based on key indicators rather than all innovations would merely assume that the innovations, not directly represented in the index, cluster around the key innovations, proportionately to their importance, and that the growth in the use of these "Satellite" innovations is concurrent with the growth of the respective key innovations. This assumption is essentially analogous to that underlying all other "key-type" economic indicators we presently use, notably the FRB index of industrial production, the Wholesale Price Index (WPI), and the Consumer Price Index (CPI), etc. As in the case of the "key-type" indicators the principal effect of this assumption would be to accord the information provided in the index lower significance than if the index were based on all innovations. The degree of significance we would attach to this information would depend on how representative we believe the key innovations to be, the degree to which the changes in the index of technological progress directly explain the changes in output per unit of total factor input (the reverse of which would indicate the degree of undercoverage), and the overall statistical consistency between the changes in the index of technological progress and the changes in the index of output per unit of total factor input.

The analytical applications of the index

It is obviously impossible to anticipate all analytical applications for which the described index of technological progress might be used. To a large extent, these applications would depend not only on how well one could define the index and the quality of information it would provide, but also on how much one knows and would learn about the process of technological change while working on it. As of now, I visualize the following potential scope of analysis for this index:

(1) Analysis of technological progress: The overall index of technological progress and the component indicators of technolgical

change composing the index would permit analysis of changes in the overall rate of technological progress in the economy as a whole as well as major technologically related sectors of the economy, the analysis of trends in major specific innovations, the analysis of areas experiencing or lacking technological change, and the like.

(2) Comparison of an economy's index of technological progress with its index of output per unit of total factor input (total factor productivity): This analysis should provide some idea as to the importance of new technology, on the one hand, and factors independent of technological change for productivity growth and, hence, for growth of GNP, on the other. The extent to which this would be achieved would depend on the comprehensiveness in the coverage of key innovations, the degree to which the changes in the index of technological progress would directly explain the changes in output per unit of total factor input, and the overall statistical consistency of changes in the index of technological progress with the changes in the index of output per unit of total factor input. With comprehensive coverage of key indicators, low undercoverage of "satellite" innovations (high degree of direct explanation of changes in output per unit of total factor input by accounted changes in technology) and reasonable statistical consistency of changes in the index of technological progress and index of output per unit of total factor input, such estimates should be reasonably accurate.

(3) The analysis of the impact of technological progress on changes in productive capacity of capital stock, changes in productive capacity and capacity utilization of the economy, the impact of new technology on society, and so forth: Such an analysis presupposes the possibility of obtaining data on the economic effectiveness of technological innovations presently not readily available and a substantial amount of research.

(4) Projection of productivity: If fully implemented, the index of technological progress in combination with the indexes of factor productivity is likely to prove a more powerful tool for projection of productivity and, hence, other major economic variables than anything that is available today. The reason for this is that most innovations take considerable time to become commercially important, and their subsequent diffusion seems to follow a regular pattern of logistic or "modified exponential" growth.

(5) International comparison of progress in technology and productivity: Because of different levels of technology and different resource endowments of different countries at any given time, the outlined approach seems to be the most promising for obtaining meaningful information with respect to the relative rates of technological progress in various countries, and the only one for obtaining information with respect to comparative levels of technology, relative effectiveness of technological progress (which undoubtedly is an important factor in international differences in returns on investment), effectiveness of different countries' institutional settings, and the like. In view of the fact that some countries might be considerably ahead of others in the

introduction and use of specific innovations, the comparisons of technological progress alone should be made in terms of worldwide key innovations rather than innovations actually used in individual countries. International differences in natural resource availability and other cost factors inhibiting technological progress would also enter into an interpretation of such comparisons.

The flexibility of the approach

Until now, I have tried to discuss the outlined approach as if there were no statistical roadblocks to its implementation. This was done in order not to complicate the exposition of the approach unnecessarily. Of course, there are statistical difficulties in its implementation, and in certain respects they are formidable. Yet, as the present study demonstrates, the approach appears to have rather wide flexibility for yielding useful information from even highly imperfect data.

The most important flexibility of the approach lies in the number of the key indicators of technological change on which the analysis is to be based. So far, my research suggests that a very accurate representation of the technological progress of any developed country might be achieved with statistics for as few as 30 to 35 key innovations, a good representation with 25 to 30 key indicators, and a reasonably good one with 15 to 20.

Moreover, the main thrust of technological change of most developed countries is likely to be concentrated around only a dozen or so innovations. This implies that reasonably good statistics are required only for the "main-thrust innovations" because more or less approximative data for the minor innovations would not materially affect the overall conclusions.

Instead of weights based on data for relative total cost savings (implied in the estimating example given earlier as ideal), the study following this approach might make use of some logical proxy weights, especially those based on relative savings of labor. In fact, this is what I do in this study. Weights based on relative savings of labor, which are much easier to estimate, are justified on the premise that the economies (factor savings or factor augmentations) resulting from technological change are largely made up of labor cost savings, and that capital savings, if any, represent some fixed proportion of the labor cost savings. The tenability of this assumption seems reasonable for the United States because the U.S. output per unit of labor input grows substantially faster than output per unit of capital input.

Finally, for most purposes of international comparisons of technological progress, the analysis may be conducted without formal construction of the indexes of technological progress but employ a shortcut; namely, a weighted relative aggregate change in individual indicators. I make use of this shortcut, too, in the present study.

II. Summary of Findings

This summary is intended primarily as a résumé for the readers not interested in the analytical aspect of the study or in detail. It should,

however, prove useful as a preview of the scope of analysis set forth in the subsequent parts for those who intend to read further. For the sake of brevity I report here only what seem to be the observations of long-run significance. These largely coincide with the overall findings for 1939–40 to 1962 and/or 1950–62.

Comparison of technological progress

The detailed comparisons of the key indicators of technological progress in the U.S.S.R. and the United States for 1939–40 to 1962 seem to warrant the following generalizations:

(1) There is probably very little of importance in the present "civilian" U.S. technology that the Soviets do not have at least on a token basis. In this judgment I obviously disregard differences in quality between the U.S.S.R. and the United States nominally the same innovations which at the time covered by this study were probably considerable.

(2) The prevailing scope of the U.S.S.R.'s use of new technology in 1962, as indicated by the 25 key indicators of technological change used in the analysis, was about the same as in the United States some time between 1939 and 1947, or about the time of World War II. This means that the overall level of Soviet technology of 1962 lagged behind the United States by some 25 years. In terms of some specific indicators this lag seems to have been as much as 40 years or more, and in terms of a few only 5 to 7 years.

(3) Contrary to general belief, the Soviets made very little use of opportunities for updating the economy's technology at the time of the wholesale reconstruction of the war-damaged economy in 1945–50. After the reconstruction (1950), Soviet technology was about at the same level as it was in 1940.

(4) In the 1940–62 period as a whole, the rate of technological change was faster in the U.S.S.R. than in the United States in the use of man-made fibers (because of a very low level of production of these fibers in the U.S.S.R. in 1940), in passenger transportation (largely because of faster growth in air transportation), and in substitution of coal for fuel wood, peat, shale, etc. (because the United States virtually completed this substitution by 1947 or thereabout). The rates of technological change were about the same in both countries in the area of electric power generation and transmission and in the area of metal cutting technology. Those two Soviet areas have enjoyed the regime's highest priority treatment ever since the beginning of industrialization. In all other areas of the new technology covered by the broad 25 key indicators, the Soviet rate of change lagged behind the United States.

(5) With respect to technological change in the United States alone, the most notable observations are that during World War II there was very little change in the U.S. technology and that the 1947–58 period witnessed much faster and undoubtedly much more profound rate of change in civilian technology than did the 1958-62 period.

In the aggregate the Soviet overall rate of technological progress, as evidenced by the extent of introduction or further diffusion of all the 25 innovations, in the 1940–62 period as a whole was about 60 percent of that in the United States, but in 1950–62 the Soviet rate was about the same as that in the United States. If the innovations in which the United States reached more or less full economic saturation by the middle of 1950's are eliminated from the comparisons, however, the Soviet overall rate of technological progress over the entire 1940–62 period decreases to slightly less than 60 percent of the United States, and for 1950–62 to about 80 percent. This obviously implies that the overall level of the Soviet economy's civilian technology in 1962 was further behind relative to the United States than in 1940.

This finding, even with all the qualifications we can reasonably make, is surprising, to say the least. It has generally been believed that because of the lower level of technology in the U.S.S.R. to begin with, the faster rate of capital formation (on the average almost three times as fast as in the United States), the centralized planning of investment, the chiefly technical background of managerial "cadres," and the practically unlimited opportunities of borrowing advanced foreign technology at little or no cost, Soviet overall technological progress must have been faster than in the United States. This is not true.

Comparison of factor productivity

The comparisons of growth in factor productivity in the two countries during the same period as the comparison of technological progress yield the following results:

The growth in labor productivity (GNP per man-year) throughout the period under analysis was consistently higher in the U.S.S.R. than in the United States. In the 1940–62 period as a whole the Soviet excess averaged 40 percent (3.3 percent per year in the U.S.S.R. compared to 2.3 percent in the United States), and in 1950–62, 80 percent (4.3 compared to 2.4 percent).

At the same time, however, the capital productivity (GNP per unit of fixed business capital input) was declining in the U.S.S.R. almost throughout the period, whereas in the United States it was increasing. The decline in the Soviet capital productivity averaged 2.2 percent per year in 1940–62 and as much as 3.8 percent in 1950–62. The U.S. increase averaged 1.5 percent per year in 1940–62 and two-tenths of 1 percent in 1950–62.

Despite the substantially higher rate of labor productivity growth in the U.S.S.R. than in the United States, the result of the disparity in the capital productivity trends in the two countries was that in the 1940–62 period as a whole the Soviet total factor productivity growth (GNP per unit of aggregated factor input with 70 percent of the total weight assigned to labor input and 30 percent to fixed business capital input) averaged only about 80 percent of that in the

United States (1.6 percent to 2 percent per year), and in 1950–62 was only about the same as in the United States (1.7 percent per year).

Since the Soviet growth in total factor productivity either lagged (1940–62) or was only on par (1950–62) with the United States, the whole secret of the highly publicized "superiority" of the Soviet overall (GNP) growth relative to the United States in those periods is fully explainable by the higher growth of physical inputs in the U.S.S.R. than in the United States. In fact, in most of the time the Soviet excess in GNP growth over the United States is fully explainable by the growth of fixed business capital alone, which was almost three times as high as in the United States. Considering the low standard of living that prevailed in the Soviet economy throughout the period capital formation at an average rate about three times as high as in the United States can hardly be attributed to economic virtues of the system, but to the dictatorial powers of the regime.

All of these comparative changes in factor productivity imply certain changes in the position of each country relative to the other. For purposes of the present study the most important are changes in the Soviet economy's factor input requirements per unit (dollar's worth) of GNP as percent of the United States since these describe the changes in the relative levels of overall productivity of the two economies. Between 1940 and 1962 the Soviet inputs per dollar's worth of GNP as percent of the United States changed in the following way: labor input, from about 395 percent to 314 percent; gross fixed business capital stock (depending on whether we assume Bulletin F service lives of capital assets in the United States or 20 percent longer), from 51 to 43 percent to 115 or 100 percent; mineral fuels input, from 67 percent to about 90 percent; input of basic metals, from about 96 percent to 160 percent; input of freight transportation (ton-miles), from 129 percent to 209 percent; and input of electric energy from 71 percent to 83 percent.

The implications of the findings in the comparisons of technological progress and factor productivity

The findings arrived at independently in the comparison of technological progress on the one hand, and the comparison of factor productivity, on the other, show a remarkable consistency: The finding of smaller rate of technological progress in the U.S.S.R. relative to the United States in the 1939–40 to 1962 period is paralleled by the U.S.S.R.'s smaller rate of growth in total factor productivity; the approximate parity in the Soviet rate of technological progress relative to the United States between 1950 and 1962 is matched by an approximate parity in the growth of total factor productivity; the decline in the U.S. rate of technological progress between 1955 and 1962 relative to the earlier decade is paralleled by a decline in the rate of the total factor productivity; and the Soviet acceleration in the rate of technological progress after 1955 relative to preceding periods is paralleled

by an improvement in the rate of growth in the total factor productivity.

The overriding implications of this consistency are twofold. First, although there are many factors that might affect the overall productivity of an economy at any given time, in the long run new technology is the force in even such diverse economies as the U.S.S.R. and the United States. Second, the "law of diminishing returns" is either not an important factor in the productivity growth in either of the two economies or, and more likely, it has operated in both economies with about the same intensity.

The findings throw a considerable light upon the causes of the Soviet economy's productivity lag behind the United States. In 1962 this overall gap constituted about 60 percentage points (i.e., the Soviet economy's productivity was about 40 percent of the United States). Based on Soviet economy's prevailing use of new technology in 1962 relative to the U.S. past and the productivity effects of the technological progress between that time (World War II) and 1962 it is estimated that the Soviet economy's lag in the use of new technology can explain only about one-fifth, or 12 to 13 percentage points, of the total gap. The other four-fifths of the gap, or 47 to 48 percentage points, must be attributed to poorer resource endowment, poorer factor proportions used in production and, above all, to poorer utilization of the resources on hand.

The findings of the two comparisons bear also upon the problem of the efficiency capabilities (the merit) of the Soviet economic system relative to the U.S. economy. Since the Soviet economy's rates of technological progress and total factor productivity growth have been smaller or at best the same as in the United States but the corresponding potentialities undoubtedly greater (because of the lower level of technology at the base period, a substantially higher rate of capital formation, an abundant availability of engineering manpower, abundant availability of natural resources, and greater opportunities for inexpensive borrowing of advanced technology abroad) the capabilities of the Soviet economy for promoting efficiency must be judged as inferior to those of the U.S. economy. This judgment, it should be noted, is not dependent on the findings with respect to the relative overall levels of productivity in the two economies but based solely on revealed relative propensities for making effective use of opportunities for technological change and, hence, efficiency growth.

Moreover, the comparison of total factor productivity growth and the rates of growth of gross fixed business capital stock (I interpret the latter as rough indicators of the relative potentialities for technological progress) in the U.S.S.R. and major European market economies indicates also that the efficiency capabilities of the Soviet economy are inferior to any reasonably developed market economy. The Soviet economy's efficiency performance has been especially poor in comparison with Italy, the market economy presumed to be

presently at about the same level of development as the U.S.S.R. economy but smaller and considerably poorer in natural resources than the U.S.S.R.

From a general analytical point of view, the two comparisons show that, in contrast to frequently expressed views, an economy's rapid growth in GNP does not automatically mean a rapid growth of efficiency, nor can an economy's rapid rate of capital formation be automatically equated with a rapid progress in technology or rapid growth in productivity.

Examples of the principal sources of inefficiency in the Soviet economy

On the basis of available information it must be concluded that the principal causes of comparative inefficiency of the Soviet economy are low propensity for making effective use of opportunities for technological change (and, hence, productiviety growth) and inefficient use of the resources on hand. Both of these factors are obviously functions of the sociopolitical system in command of the economy. This is, of course, what many writers have argued for a long time. The chief features of the Soviet system that inhibit efficiency growth are obviously the lack or, at least, frequent disregard of economic calculus in planning in general, and in investment planning in particular (in the current critical Soviet parlance—"voluntaristic" decision-making), poor business organization, lack of proper incentives, and lavish (compared to the economy's means) cultivation of the industrial defense establishment.

The best example of voluntaristic decisions, and which probably contributed to the tardiness of Soviet technological progress and decline in capital productivity more than anything else throughout the period under study, was undoubtedly Stalin's decision to base Soviet industrialization almost exclusively on coal. This decision proved detrimental to the development of oil and gas industries, and this, of course, was extremely detrimental to technological progress. To a large extent, Khrushchev probably paralleled Stalin's blunder with his bet on the virgin lands. The classical example of decisions in which the strictly engineering rather than economic criteria were used in the long-range planning was undoubtedly the decision for the development of huge electric steel melting capacity and the scrapping of the Bessemer converter process.

Poor business organization, and also to some extent lack of proper economic calculation, in turn, is evidenced by irrational disproportionalities in the planning of production of various capital goods, the lengthy construction and reconstruction cycles of production facilities, the haphazard system of distribution of capital goods, lack of proper incentives, and inefficient use of industrial materials, notably metal.

The inhibition of efficiency by the industrial defense establishment cannot, of course, be argued in terms of specific examples. However, it seems hardly possible to conclude otherwise in view of the evidence

that at least in the past 5 years or so this establishment has grown at the rate substantially greater than twice the rate of growth of the economy and by 1963 achieved the absolute level equal to or greater than that of the United States despite the fact that the overall size of the Soviet economy was still less than half that of the United States.

The prospects

Based on incomplete analysis it appears that between 1962 and 1965, the time not covered in the basic body of my analysis, the aggregate Soviet (civilian) technological progress was advancing at a somewhat faster rate than as that in the United States. The growth in total factor productivity, however, drastically declined in the U.S.S.R. at that time, while in the United States it substantially increased, largely because of expanded capacity utilization. As has been widely heralded in the press, the relative overall rate of economic growth declined in the U.S.S.R. in those years along with productivity while in the United States this rate of growth increased. This caused great concern in the Kremlin and subsequent search for remedies.

Looking forward from 1965 to 1970, Soviet prospects seem as mixed as they were in the distant past, but probably rosier than during the 5 years in the most immediate past. The regime's renewed determination to increase the rate of technological progress is likely to meet with success. The most important factor favoring this projection is the room for progress. As noted earlier, the overall level of the Soviet economy's technology in 1962 was behind that of the United States by some 25 years, but on at least a token basis it had practically all the new know-how that the United States had. Hence, the potentialities for further progress in technology are still practically limitless. Other factors favoring such a projection are an apparently more genuine concern about the lag by the regime, expected continuation of high rate of capital formation, and most probably even greater access to advanced foreign technology than was the case in the past.

The improvements in total factor productivity, however, are not so certain. These will depend largely on how rapidly the downward growth trend will be reversed and how far the regime will go in "rationalization" of the system (minimizing arbitrary or noneconomic decisions and improving business organization), and whether it will arrest the growth of the industrial defense establishment. It seems quite likely, however, that with an accelerated rate of technological progress, a more or less stabilized (relative to GNP) growth of the defense establishment and a small reduction of institutional inefficiencies (involving an elimination of only apparent blunders), the regime might regain the economy's long run (1950–62) growth rate in total factor productivity (1.7 percent per year).

With the growth in total factor productivity by about 1.7 percent per year and an estimated growth of labor input by about 2.3 percent per year (about the same as in 1950–62), growth of fixed business capital stock about three-fourths as high as in 1950–62 (about 7 to 8 percent compared to 10.5 percent in 1950–62), and no excessively adverse climatic conditions, the Soviet economy (GNP) is likely to grow at about 5.5 percent per year. This is not as rapid as in 1950–62, but substantially faster than in 1960–65.

In projecting the U.S. GNP growth through 1970, I assume that the growth of U.S. labor input will be about 1.9 percent per year (which assumes a 4-percent unemployment rate), that the average rate of capital formation will be about 4 percent, which is 25 percent higher than the average in 1950–62, that the rates of technological progress and total factor productivity will be about the same as in 1950–62, and that the resultant (real) GNP growth rate will average about 4 percent per year.

The projected comparative growth rates imply that the output (GNP) of the Soviet economy will increase by 1970 to about 51 percent of that of the United States, which will represent a relative gain of 3.5 percentage points in the 5-year period; the Soviet economy will also succeed in reducing a little its technological gap, but its relative gap in overall productivity will remain the same as it was in 1950, and even slightly larger than in 1940.

The broad generalizations set forth in this summary are, of course, subject to qualification and amplification. This can only be done in the context of the detailed analysis of the data in the parts that follow.

III. Comparison of Technological Progress

THE DATA AND THE SCOPE OF ANALYSIS

The comparison of technological progress is primarily based on the extent to which the two countries introduced and further diffused "new technology" between 1939–40 and 1962, and in certain subperiods, defined in terms of 15 sets of important worldwide key indicators of "civilian technological change" embracing about 25 specific indicators. The impact of these changes affects either the economy as a whole or its major sectors: the industry, including such important branches as the generation and transmission of electrical energy and metalworking; transportation; communications; and agriculture. The time span covered, in turn, embraces practically the whole period of "mature" functioning of the Soviet economic system.

The statistical summary of these indicators is presented in table 1.

TABLE 1.—*Key indicators of technological change in Soviet economy between 1940 and 1962 compared to the United States*

Indicator	Union of Soviet Socialist Republics					United States				
	1940	1950	1955	1958	1962	1939	1947	1954	1958	1962
Item:										
1. Percentage distribution of mineral fuels and fuel wood consumed in the economy (calorific content) by type (percent of total):										
Coal	59.9	66.2	65.8	60.5	52.3	50.4	47.8	28.5	24.7	22.5
Oil	18.1	17.8	20.0	23.9	28.7	31.2	33.2	42.2	42.8	42.1
Gas	1.8	2.3	2.4	5.7	12.1	12.4	15.3	26.2	30.1	33.4
Other (wood, peat, etc.)	20.2	13.7	11.8	9.9	6.9	6.0	3.7	3.1	2.4	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2. Consumption of electric energy per production worker in manufacturing and extractive industries by use (kilowatt-hours/man-year):										
Total consumption	3,499	4,967	7,564	(1)	11,492	8,749	11,084	19,023	23,289	28,771
For motive power	2,398	3,232	4,714	(1)	7,122	(1)	(1)	(1)	(1)	(1)
For technical processes	632	1,165	2,012	(1)	3,288	(1)	(1)	(1)	(1)	(1)
2a. Same, percentage change from base period (percent):										
Total consumption	100	142	216	----	328	100	127	217	266	329
For motive power	100	134	197	----	297	----	----	----	----	----
For technical processes	100	184	318	----	520	----	----	----	----	----
3. Installed mechanical power per production worker in industry (horsepower production per worker)	0.22	0.25	0.29	(1)	0.51	(1)	(1)	(1)	(1)	(1)
3a. Same, percentage change from base period (percent)	100	114	132	----	232	[2][100]	[2][127]	[2][217]	[2][266]	[2][329]
4. Changes in percentages of installed electricity generating capacity by type (percent of total):										
Thermal	85.8	83.6	83.9	79.7	77.4	75.6	75.5	79.6	81.3	81.8
Hydro	14.2	16.4	16.1	20.3	22.6	24.4	24.5	20.4	18.7	18.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4a. Maximum rated unit capacity of electricity generating steam turbines in use in the economy (megawatts (1,000 kilowatts))	100	100	150	200	300	208	208	260	335	650

4b. Length of extra high (over 400 kilovolt) voltage electric transmission lines (miles)				1,677	4,424					13
5. Percentage distribution of steel-ingot equivalent tonnage of basic metals consumed in the economy by type (percent of total):										
(a) Steel	96.67	(1)	95.26	96.06	95.34	94.00	92.30	90.07	89.08	89.43
(b) Aluminum	.99	(1)	2.94	2.13	2.98	1.20	3.05	5.37	6.80	7.14
(c) Magnesium	.05	(1)	.11	.14	.18	.03	.12	.23	.22	.23
(d) Zinc	.69	(1)	.61	.59	.53	1.68	1.41	1.44	1.23	1.10
(e) Copper	1.16	(1)	.68	.74	.72	2.13	2.20	1.96	2.90	1.40
(f) Lead	.44	(1)	.40	.34	.25	.96	.92	.93	.77	.70
Total	100.00		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
6. Percentage output of steel by type of process (percent of total):										
(a) Open hearth	84.8	89.9	88.1	86.6	85.1	91.7	90.5	91.0	89.0	84.4
(b) Bessemer	9.3	3.8	4.4	3.0	2.5	6.4	5.0	2.9	1.6	.8
(c) Electric	5.9	6.3	7.5	8.2	8.9	1.9	4.5	6.1	7.8	9.2
(d) Oxygen converter				2.2	3.5				1.6	5.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7. Inventory of metalworking machine tools in the economy by type (thousand):										
Metalcutting	710	(1)	1,699	1,915	2,442	(1)	[4] 1,762	[5] 2,299	2,139	2,467
Metalforming	119	(1)	345	394	497	(1)	[4] 471	[5] 667	679	811
Total	829	(1)	2,044	2,309	2,939	[3] 1,332	[4] 2,233	[5] 2,966	2,818	3,272
7a. Same, change of "total" from base period (percent)	100		247	281	358	100	169	224	213	248
7b. Same, percentage composition by type (percent of total):										
Metalcutting	85.6		83.1	82.9	83.1	(1)	78.9	77.5	75.9	75.4
Metalforming	14.4		16.9	17.1	16.9	(1)	21.1	22.5	24.1	24.6
Total (percent)	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7c. Output of numerically (tape) controlled machine tools (units)				14	135				[6] 98	1,047
8. Output of synthetic resins and plastics (thousand short tons)	16.4	82.1	195.4	283.8	521.5	106.5	625.7	1,475.2	2,429.0	4,049.2
8a. Same, percentage change from base period (percent)	100	500	1,190	1,728	3,175	100	588	1,385	2,281	3,803

See footnotes at the end of table, p. 159.

TABLE 1.—*Key indicators of technological change in Soviet economy between 1940 and 1962 compared to the United States*—Continued

Indicator	Union of Soviet Socialist Republics					United States				
	1940	1950	1955	1958	1962	1939	1947	1954	1958	1962
Item—Continued										
9. Output of man-made fibers (100 percent) (thousand short tons)	11.2	24.6	112.1	183.0	305.3	200	513.3	714.8	814.6	1,216.4
9a. Same, percentage change from base period (percent)	100	220	1,000	1,634	2,726	100	257	357	407	608
10. Ratio of engineering and technical personnel to production workers in industry (manufacturing, mining and utilities) (percent)	9.7	9.4	9.7	9.6	10.2	[7] 3.3	[8] 5.0		[9] 8.3	
11. Use of automatic data processing equipment in the economy (computors and punched cards systems) (number)		(1)	(1)	(1)	[10] 6,200		(1)	(1)	(1)	[10] 50,000
12. Percentage distribution of all freight traffic by type (percent of total): [11]										
Railroads	85.1	84.4	83.3	81.2	77.8	62.3	65.2	49.5	46.6	43.7
Waterways	12.3	12.1	11.7	11.9	13.4	17.7	14.4	15.5	15.4	15.8
Pipelines	.8	.7	1.3	2.1	3.5	10.2	10.3	15.9	17.2	16.9
Automotive	1.8	2.8	3.7	4.8	5.3	9.8	10.1	19.1	20.8	23.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
13. Percentage distribution of all intercity passenger traffic by type (percent of total): [12]										
Railroads	95.3	93.1	91.3	86.8	79.3	9.9	14.2	4.7	3.4	2.5
Waterways	4.5	4.1	3.3	3.0	2.5	.7	.6	.3	.3	.3
Automobiles	.9	1.5	3.6	6.7	9.7	89.1	83.3	91.9	92.3	92.5
Airways	.2	1.3	1.8	3.5	8.5	.3	1.9	3.1	4.0	4.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
14. Number of telephones in the economy [13] (thousands)	1,225	1,410	1,932	2,370	3,215	20,831	34,867	52,806	66,645	80,969
14a. Same, percentage change from base period (percent)	100	115	158	193	262	100	167	253	320	389

15. Agriculture:										
(a) Use of tractors (units per 1,000 acres of harvested cropland)	1.43	1.65	1.83	2.07	2.49	4.37	7.36	12.26	14.72	15.90
(b) Use of grain combines	.49	.58	.74	1.04	.97	.57	1.31	2.79	3.31	3.47
(c) Use of motortrucks	.61	.78	1.18	1.45	1.64	3.08	4.78	7.51	8.86	9.74
(d) Use of primary commercial fertilizer (100 percent nutrient content) (short tons per 1,000 acres of harvested cropland)	2.21	3.85	4.86	5.72	6.31	4.82	9.24	17.0	20.61	28.64
15a. Same, percentage change from base period (percent):										
(a) Use of tractors	100	115	128	145	174	100	168	280	337	364
(b) Use of grain combines	100	118	151	212	198	100	229	489	581	609
(c) Use of motortrucks	100	128	193	238	269	100	155	244	288	316
(d) Use of primary commercial fertilizer	100	173	219	258	285	100	192	355	429	596

[1] Not available.
[2] Assumed minimum growth. The rationale is explained in the text.
[3] 1940.
[4] 1949.
[5] 1953.
[6] Assumed to be ½ of the output in 1954–58.
[7] 1940.
[8] 1950.
[9] 1960.
[10] For U.S.S.R., in 1962; for the United States, as of end of 1963.
[11] Derived from: U.S.S.R.—data on all freight traffic by public means; United States—intercity freight traffic.
[12] Derived from: U.S.S.R.—data on all passenger traffic by public means except city electrocar, city buses and taxis; United States—intercity passenger traffic. Figures do not necessarily add exactly to 100 because of independent rounding.
[13] U.S.S.R.—telephones under the jurisdiction of the Ministry of Communications; United States—all telephones.

Sources: U.S.S.R.—Tsentral'noe Statisticheskoe Upravlenile pri Soviete Ministrov SSSR, Narodnoe Khoziaistvo SSSR, Statisticheskii Ezhegodnik (National Economy of the U.S.S.R., statistical yearbook) for 1958, 1960 and 1962; idem, Promyshlennost'SSSR, Statisticheskii Sbornik (The Industry of the U.S.S.R., Statistical Symposium), Moscow, editions of 1957 and 1964; idem, Vnieshnaiia Torgovla SSSR (Foreign Trade of the U.S.S.R.), editions for 1913–40, 1956, 1959 and 1963; N. I. Kovalev, Vychislitel'naia Tekhnika v Planirovanii (Computor Technology in Planning), Moscow, 1964; Joint Economic Committee of the U.S. Congress, Annual Economic Indicators for the U.S.S.R., Washington, D.C., 1964; and data collected in Soviet periodicals.

United States—U.S. Department of Commerce, Bureau of the Census, "U.S. Census of Population" for 1940, 1950 and 1960; idem, "Historical Statistics of the United States," "Colonial Times to 1957; idem, "Statistical Abstract of the United States," editions for 1948, 1955, 1959 and 1964; idem, Census of Manufactures for 1939, 1947, 1954, 1958 and preliminary data for 1963; and Current Industrial Reports (formerly Facts for Industry) series M22P, M30D and BDSAF 630. U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook for 1940, 1948, 1955, 1959 and 1963; U.S. Tariff Commission's estimates of U.S. production of plastics; U.S. Power Commission, "National Power Survey, Guidelines for the Growth of the Electric Power Industry," Washington: October 1964; Perry D. Teitelbaum, Energy Production and Consumption in the United States: An Analytical Study Based on 1954 Data, Bureau of Mines Report of Investigations No. 5821, Washington, D.C., 1961; Sam H. Schurr et al, Energy in the American Economy, 1850–1975, The Johns Hopkins University Press, 1960; U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings Statistics for the United States, 1909–64, bulletin No. 1312-2; U.S. Department of Agriculture, Changes in Farm Production and Efficiency, A Summary Report, 1964 (statistical bulletin No. 233); "Control Engineering," Estimates of Computor Use in the United States; U.S. Bureau of the Budget, 1964 Inventory of Automatic Data Processing (ADP) Equipment in the Federal Government, Washington, D.C., 1964; American Machinist's (McGraw-Hill Co.) inventories of metalworking equipment for 1940, 1949, 1953, 1958 and 1962; American Iron and Steel Institute's annual reports, and unpublished data from Atomic Energy Commission.

As is evident from this table, most of the data are in physical terms. This has advantages as well as disadvantages. Data in physical terms are usually fairly reliable even for the U.S.S.R. Unfortunately, they do not account for quality differences in whatever they stand for. This obviously must be taken into account when summary conclusions are drawn.

In addition to the 25 key indicators covered in the 15 sets given in table 1, for judgments with respect to technological change in the metalworking industries of the 2 economies, I also use data on some 20 other specific metalworking innovations in the process of diffusion in the 2 countries as of the end of 1962, which I summarized in my previous study mentioned earlier.

While it cannot be claimed that the information I assembled bears on everything that might be described as a worldwide technological change of the last 25 years or so, this information does cover the bulk of such changes, either directly or indirectly. At the minimum the indicators used can be considered as a good sample, and this is just about all that can realistically be hoped for in international comparisons.

The analysis of this information consists of two phases.

In the first phase, the comparisons of the indicators in detail, the primary focus is on the economic significance of the technological changes represened by the individual indicators and the rapidity with which the Soviet economy was introducing or further diffusing the use of the innovations relative to the United States both over the 1940–62 period as a whole and during certain subperiods when notable developments took place. In addition to the discussion of the economic significance of the innovations and the relative rates of change, based on the data listed in table 1 and some additional information, I also try to determine the 1962 Soviet economy's technological lag relative the United States in the areas represented by the indicators. Inasmuch as differential trends apparent in the individual indicators represent the results of deliberate actions taken in the two economies, this phase of the analysis might be considered a study of the technological policies pursued by the two economies. The discussion follows the same sequence as the listing of the indicators in table 1 and, in effect, amounts to 15 case studies.

The second phase represents an attempt to generalize from the detailed conclusions reached in phase 1.

THE COMPARISON OF THE KEY INDICATORS OF TECHNOLOGICAL CHANGE IN DETAIL

(1) *Percentage distribution of mineral fuels and wood fuel consumed in the economy*

This is one of the most important indicators of technological change in the sample. Its rationale is that, on one hand, the greater the aggregate share of natural gas and oil and, inversely, the smaller the aggregate share of coal, peat, shale and fuel wood in an economy's total consumption of fuel, the more efficient is its technology. If an economy's technology is basically oriented to nonoil and nongas fuels, then the greater the share of coal and, inversely, the smaller the share of

peat, shale and fuel wood, the more efficient it will operate. The reason for this is that, per unit of thermal energy (B.t.u. or calorie), natural gas and oil fuels require less resources to extract, process, transport and/or use than coal, and coal requires less resources than other kinds of fuels. It is conceivable that this proposition might not hold in all countries, but there is no doubt as to its validity in either the U.S.S.R. or the United States. In fact, Soviet planners claim that substitution of oil and gas for coal in the Soviet economy results in a total unit cost saving of, respectively, 60 to 70 and 80 to 95 percent, an increase in labor productivity of 300 to 400 and 1,200 to 1,300 percent, and a unit capital savings of 50 to 60 and 70 to 80 percent (see app. A, table 1). Although no such data are available for the United States the trends in the use of oil and gas versus coal, and coal versus other types of fuels suggest that here, too, the economic advantages resulting from their use are considerable.

As shown in the table, the combined share of oil and gas in the total fuel consumption of the Soviet economy increased from 19.9 percent in 1940 to 40.8 percent in 1962, a relative gain for the "most efficient" fuels of almost 21 percentage points in the 22-year span. The combined share of coal and "other" fuels correspondingly declined, from 81.1 percent in 1940 to 59.2 percent in 1962. The share of coal, however, declined proportionately much less than "other" fuels, which indicates that there had been substitution of coal for "other" fuels during the time. It will also be noted that in 1950 the proportional relationship between oil and gas in all fuels was virtually the same as in 1940, but the ratio of coal to "other" fuels increased. This indicates that in the post-World War II reconstruction of the Soviet economy the orientation on coal was even heavier than at the beginning of the industrialization. The relative switch to oil and gas got underway only after 1955.

The share of oil and gas in the U.S. economy increased over the 23-year span by roughly 32 percentage points, from 43.6 in 1939 to 75.5 percent in 1962, or about 10 percentage points more than in the U.S.S.R. About two-thirds of the total relative gain occurred between 1947 and 1954. By 1954 the use of coal and "other" kinds of fuels had apparently been reduced to practically a bare minimum. After 1954 the relative use of gas continued to increase but at a much slower ("mature") rate than in earlier years, partly further displacing coal and partly at the relative expense of oil.

In the 1939/40–1962 period as whole, the Soviet rate of technological change thus lagged behind that of the United States in terms of substitution of oil and gas for coal and "other" fuels, but outpaced the U.S. rate of change in terms of the substitution of coal for "other" fuels. In the 1950–62 period, and particularly in the 1955–62 period, however, the Soviet rate of change was faster in both respects. The better Soviet performance relative to the United States in the latter period was clearly partly due to an increased effort and partly due to the "maturity" of the changes in the United States.

The Soviet pattern of the fuel consumption in 1962 was almost identical with what the United States had in 1935. It should also be of interest to note that a comparable change toward the "efficient" fuel types made by the U.S.S.R. between 1940 and 1962, a span of 22 years,

about 5 of which were war years and 5 were large-scale reconstruction years, was carried out in the United States in 15 years, from 1920 to 1935, 6 of which were depression years.[19]

(2) *Consumption of electric energy per production worker in the manufacturing and extractive industries*

Although in industry electric energy can be used for a great variety of purposes and with varying degrees of effectiveness, the bulk of it is undoubtedly consumed for driving industrial equipment; that is, mechanization and automation, and electrotechnology (processes). It seems safe, therefore, to assume that an increase in the consumption of electric energy per unit of output, or per production worker, particularly if the gain is large, is caused by the increases in mechanization or automation and increases in the use of electrotechnology. These, in turn, result in increased productivity and reduced cost.

As shown in table 1, between 1940 and 1962 the Soviet manufacturing and extractive industries increased the consumption of all electric energy per production worker by 228 percent, which is equivalent to an average rate of growth of about 5.5 percent per year. The fastest growth period was by far 1950–55 (8.7 percent per year), followed by 1955–58 (6.2 percent); the slowest was 1940–50 (3.2 percent). Of considerable interest is also the fact that the Soviet use of electricity per production worker for electrotechnology (processes) grew on the average some 60 percent faster than the average use for all purposes and 75 percent faster than the use of electricity for motive power.

In U.S. manufacturing and extractive industries the consumption of electric energy per production worker increased over the entire period by virtually the same percentage as in the U.S.S.R. although in recent years the U.S. percentage increase was slightly smaller than in the U.S.S.R. There are no data on the use of electric energy in U.S. industry by type (for motive power versus electrotechnology), but it seems reasonable to presume that the U.S. use of electrotechnology also grew faster than its use of motive power, but not by as great a margin as in the U.S.S.R.

Taking these data at face value we must conclude that in terms of electric energy consumption per production worker the Soviet rate of technological change was about the same as in the United States in the 1940–62 period as a whole, but from 1950 to 1962 was slightly faster than in the United States. One might argue, however, that in terms of the effective use of electric energy the Soviet rate of change was at best the same as in the United States in both periods. The reason for this is that since about 1950 the Soviet machine-building industry, in an effort to reduce manufacturing cost, has been building more and more "unified" (less and less tailor-made) equipment, which is less efficient in terms of input of energy to output than the tailor-made machines. The U.S. trend has been the reverse of the Soviet practice. It seems quite likely, therefore, that the inefficiency of Soviet machinery and equipment because of "unification" could alone have caused the Soviet consumption of electric energy since 1950 to grow faster than in the United States by at least the margin implicit in the data given in the table.

[19] Cf. Sam H. Schurr, et al., "Energy in the American Economy, 1850–1975," the Johns Hopkins University Press, 1960, appendix, table VII, pp. 511–513.

As shown in the table the Soviet consumption rate of electric energy in manufacturing and extractive industries of 11,492 kilowatt-hours per (production) man-year constituted about 40 percent of that in the United States in that year and was on par with the U.S. consumption in about late 1947. The consumption rate of about 3,500 kilowatt-hour per production man-year in those industries, which prevailed in the U.S.S.R. in 1940, was prevalent in the United States in early 1921.[20] Thus the progress made in the U.S.S.R. in 22 years including the five World War II years took the United States 26 years, about half of which were depression and war years.

(*3*) *Changes in the use of mechanical power per production worker in industry*

In industrial technology, consumption of electric energy is usually associated with direct production processes performed on factory floors. Consequently, the indicators of changes in consumption of electric energy bear little on changes in the technology of factory indirect production operations, particularly material handling and intraplant transport, and probably even less on changes in the technology of mining because in these activities technology involves principally mechanical rather than electric power. The present indicator furnishes this additional information.

As shown in item 3a of the table, the installed mechanical power (measured in horsepower) per production worker increased during the 22 years in Soviet industry by 132 percent. Through 1955 the increase was very slow, not quite 2 percent per year, but since 1955 it has been more than four times as high. On the average, however, the use of mechanical power and, hence, the mechanization in the areas delineated above has grown at a rate about two-thirds of the rate in the areas represented by the growth in the use of electricity.

Statistics on the use of mechanical power in U.S. industry are not readily available. However, judging by the fact that the growth in the U.S. output of construction, mining and material handling machinery and equipment, including industrial trucks and tractors (all of which are usually driven by mechanical power) has been considerably faster than the output of electric motors, generators, and apparatus[21] I assume, therefore, that the use of mechanical power in U.S. industry has grown at the minimum as fast as the use of electric power. Consequently, the rate of technological change in the form of increased use of mechanical power per production worker in Soviet industry has been at best about two-thirds of the U.S. rate.

It might be noted that this assumption is consistent with the finding in my earlier study that in 1958 Soviet productivity of labor in the machine building industry lagged behind the United States most in the operations of material handling, storage, and intraplant transportation,[22] that is, the areas where increased mechanization usually is in the form of increased use of mechanical power.

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[20] Cf. "Historical Statistics of the United States, Colonial Times to 1957," table S 81–93, p. 511, and John W. Kendrick, "Productivity Trends in the United States," Princeton University Press, 1961, table A–VI, pp. 305–307, and U.S. Department of Labor, BLS, Employment and Earnings Statistics for the United States, 1909–64, Bulletin No. 1312–2.

[21] Cf. Corresponding products statistics in the Bureau of the Census, Annual Survey of Manufacturers, Product Statistics, 1950–62.

[22] Cf., "The Soviet Challenge," op. cit., pp. 16–17.

Because it would be highly speculative I make no attempt to pinpoint the 1962 Soviet level of mechanical power use per production worker in industry relative to the U.S. historical experience as I have done in the discussion of most other indicators.

(4) *Major changes in the technology of generation and transmission of electric energy*

Following Lenin's command,[23] the electrical utilities industry has enjoyed undoubtedly the highest priority in regard to investment and human talent of any industry in the Soviet Union since its beginning. Technological progress in this industry might, therefore, be viewed as a showcase of the system's maximum capabilities. The most eloquent yardsticks of this progress are: the trend in the installation of generating capacity by source of energy—thermal versus hydropower, changes in maximum rated unit capacity of steam turbines used in the production of electricity, changes in the length of extra high (over 400 kilovolts) voltage transmission lines, and changes in the proportions of total electric energy consumption supplied by integrated (interconnected) systems. The proportion of total electric energy generated by means of nuclear power or some other measure of the role of atomic energy in this industry would be a desirable addition to these four indicators, but this role is still too small to warrant a large research effort to overcome the dearth of readily available information. The rationale of the four indicators used in the analysis, however, requires a short digression into the history.

Today, as 30 or 50 years ago, the two principal sources of power for the generation of electric energy are "water wheels" and steam turbines. Through about 1930 the use of "water wheels," largely in the form of Kaplan type turbines for low head sites, Francis type turbines for medium head sites, and impulse type turbine for mountain head sites, had been much more economical means of generating electric energy than steam turbines. Hydropower stations, although per kilowatt of installed capacity more costly than thermal stations, did not need fuel (coal, gas, or oil) to produce the power. Up to that time the unavailability of appropriate water streams in energy-transmittable distances from the users was the only reason why steam turbines and other thermal equipment were used at all.

Largely since 1930, however, the differential trends in improvements have gradually changed the economics of the two methods to the point that now in many instances hydropower is preferable to steam power only because of by-products of hydro installation, such as flood control, construction of irrigation or recreation facilities, etc., rather than the cost of electricity as such.

The most important innovations that have tended to foster the use of hydropower are improvements in the design of water turbines and in the designs of whole installations. The improvements in designs of the turbines were aimed at greater unit capacity, increased efficiency, and greater flexibility in adapting to various sites. The improvements in the design of the whole installations have largely been directed at multipurpose projects, such as generation of power and flood control, power and irrigation facilities, power and recreational facilities, or a combination of all of them. All of this has tended to reduce the capital cost and operational cost of the hydropower projects per unit of capacity and output, but less so relatively than the developments that favored the use of steam turbines.

The most important innovation that favored relative expansion in the use of steam turbines has been a gradual development of high-pressure-high-temperature, boiler-turbine-generator combination equipment with increasingly large unit capacities. By 1965, the capacity of a single turbine reached about 1.1 million

[23] I refer here obviously to Lenin's familiar slogan: "Communism means the Soviet rule plus electrification of the country" and to the plan for electrification of the Russian Republic (GOERLO plan) prepared at Lenin's request in 1920.

kilowatts. Per unit of capacity the installations using large turbogenerators cost only about half of what the cost was in the late 1920's or thereabout. Also, the cost of operating such large units is much less because the fuel input per kilowatt-hour of output is drastically reduced, and necessary attendant labor and space lessened.

In the United States and some other countries the technological improvements favoring expanded generation of electric energy in steam turbines have also been vastly augmented by decreases in the cost of coal made possible by dramatic increases of productivity in coal mining and improvements in the transportation of coal from mines to power stations.

Innovations that thus far have been more or less neutral to both methods are the development of techniques for extra high voltage (EHV) transmission of electric energy over long distances and interconnection of individual systems into regional and countrywide supply systems by means of automatic controls. The first of these permits transmission of energy over longer distances (up to some 1,500 miles) than was possible before (350 miles) and at a cost no greater than the former cost for short distances. It thus stimulates large capacity thermal generation as well as generation of hydropower at sites farther away from users than was previously practical. The second tends primarily to increase the utilization of existing capacity and thus to minimize the additions to the capacity with growing demand for the output.

All of these technological innovations have important productivity implications.

Despite a faster rate of technological progress in the area of thermal generation of electric energy, the relative share of generating capacity of Soviet thermal stations, as shown in table 1, declined from 85.8 percent in 1940 to 77.4 percent in 1962, or 8.4 percentage points over the 22-year period. At the same time, the share of hydro stations increased by the same magnitude, from 14.2 percent in 1940 to 22.6 percent in 1962.

Readers who have studied the literature on economic developments in the U.S.S.R. will probably recollect that this overwhelming preference of Soviet planners for hydro power has been assailed in the Soviet press, and abroad, as an irrational waste. Academician Chukhanov,[24] for example, has claimed that because of the emphasis on hydro power rather than thermal power the Soviet people lost about 4 billion rubles in 1952–58 alone and that these losses would multiply several-fold if the preference is continued through the 7-year plan and into the 20-year plan. Khrushchev, too, appeared to be not very enthusiastic about the preference.[25]

Although the available information does not permit one to be very categorical about the accuracy of such accusations, it seems to me that the losses are grossly exaggerated. Undoubtedly, by pushing the development of hydro power more than the development of thermal power, Soviet planners were foregoing some magnitude of relative progress in the electric power industry because, as noted earlier, progress has been faster in the area of thermal power than in the area of hydro power. Moreover, because of the construction of more of the new hydro projects farther and farther away from the centers of demand for energy and in low-head sites with capricious water flows, the expansion of the industry based on hydro power has required long construction periods and probably four times as much capital as would

[24] Based on reference made in "Dimensions of Soviet Economic Power," op. cit., pp. 701–703.
[25] Pravda, Aug. 11, 1958.

have been needed had the expansion been based on thermal power.[26] It is unlikely, however, that the average total cost per kilowatt-hour of energy produced in these capital-intensive hydro projects would be appreciably higher than in new thermal power stations. Whatever the excess, it is probably at least in part offset by the benefits derived from byproducts of the hydro projects, particularly the increased flood controls, improved navigability of the rivers, and enlarged irrigation facilities. The program could be termed "wasteful" only with reference to (scarce) capital requirements, but probably not if the average cost is used as reference.

Despite the decline in the relative importance of electricity generated from thermal sources, the threefold increase in the maximum unit capacity of steam turbines in use between 1940 and 1962 suggests that technological progress in this area was not neglected either. In 1962, work was well underway to produce a steam turbine with a unit capacity of 800,000 kilowatts[27] or eight times the maximum unit capacity used in 1940 and 1950.

Even more impressive progress was achieved by the Soviet industry in the area of extra high voltage transmission of electric energy. The experimentation started only in the early 1950's, but by 1958, 1,677 miles of such lines were already in use, and by 1962 the mileage had increased to 4,424. The latter figure included 294 miles of 800 kilovolt line between Volgograd and Don Basin, put into operation in 1962.[28] However, the progress in extra high voltage transmission lines is apparently not synonymous with the buildup of interconnections between the individual supply systems. The former was apparently the result of a concentrated effort to make use of the tremendous expansion of hydropower capacity at sites far away from users or to cut down on losses of energy in conventional transmission lines transmitting the energy over distances that were too long.

The progress in the construction of interconnections of the 60 or so individual electric energy supply systems presently in existence in the U.S.S.R. has been less impressive. By 1962 partial interconnection covered only about 50 percent of the generating capacity located in central Russian territory, the Ukraine, the Volga River region, and parts of the Urals.[29]

In contrast to the U.S.S.R., the U.S. trend has been toward the increased importance of thermal power. In 1939 the generating thermal power capacity installed in the United States constituted 75.6 percent of the total while that of hydropower constituted 24.4 percent. By

[26] The ratio of investment requirements per kilowatt of installed capacity in hydro and thermal power stations in the U.S.S.R. is normally 2 to 1 or more (see T. S. Khachaturov, "Ekonomicheskria Effektivnost," op. cit., p. 187). According to the Federal Power Commission, the U.S. typical capital cost per kilowatt for steam plants was $130, internal combustion units $145, and hydropower plants $208, that is, the prevailing ratio is about 1.5 to 1. (See Albin Kaufman, "Geothermal Power, An Economic Evaluation," information circular 8230, U.S. Department of the Interior, Bureau of Mines, p. 11.) For the expansion of the Soviet electric energy plants in 1959–65, the plan apparently assumed the capital investment in hydro projects per kilowatt capacity four times the investment in thermal plants. (See Iu. E. Maksarev, "Tekhnicheskii Progress v Promyshlennosti SSSR v 1959–65 godakh" (Technical Progress in the U.S.S.R. Industry in 1959–65), Znaniie, Moscow, 1959, p. 7.)

[27] Promyshlennost' SSSR 1964, p. 23.

[28] Ibid., p. 236.

[29] F. N. Sheviakov, "Tekhnicheskii Progress i Struktura Proizvodstva" (Technical Progress and Structure of Production), Ekonomika, 1963, p. 24, and Iu. N. Astakhov et al., "Kibernetika v energetike" (Cibernation in Electric Power Industry), Znaniie, Moscow 1962, p. 10.

1962, however, the relative share of the thermal power capacity increased 6.2 percentage points, to 81.8 percent, and that of hydropower declined by as much, to 18.2 percent. The Federal Power Commission anticipates that by 1980 the relative share of hydropower generative capacity will decline further to approximately 14.5 percent of the total.[30]

The relative expansion in the U.S. use of thermal power between 1939 and 1962 was accompanied by a phenomenal growth in unit capacities of steam turbines. In 1939 the greatest turbine used in the United States had a rating of 208 megawatts, but by 1962 this increased more than 300 percent to 650 megawatts. In 1964, according to the Federal Power Commission,[31] a turbine rated at more than 1 million kilowatts in a single unit was under construction. The Federal Power Commission projects that conventional steam generating equipment with unit capacities of 1.5 million kilowatts will be in use in the United States by about 1975.[32]

The U.S. progress in extra high voltage transmission has been slow up to now. In 1962 the U.S. utilities' transmission voltages ranged between 69 to 345 kilovolts. About 4,000 circuit miles were at 345 kilovolts. The Pennsylvania Electric Co. had an experimental line of 13 miles at 460 kilovolts. According to the Federal Power Commission, however, several extended extra high voltage lines are presently under construction or planned, and by 1967 more than 3,000 miles of 500-kilovolt lines are expected to be in service.[33] It is also expected that by 1980 transmission lines of 700–750 kilovolts will be commonplace in the United States.[34]

Despite slow progress in the expansion of extra high voltage transmission, U.S. progress in interconnection and coordination of individual power supply systems has been underway since the 1920's.[35] As of about 1962, approximately 97 percent of U.S. electric energy generating capacity was in varying degrees interconnected in five large networks, the largest of which covers the entire Eastern United States—east of Texas and the Rockies as well as much of Eastern Canada.[36] The Federal Power Commission envisages that by 1980 practically all electric energy supply systems of the United States and much of Canada will be fully coordinated.[37]

On the basis of this information it seems reasonable to assume that in the area of electric power generation the U.S.S.R. rate of technological progress has been somewhat smaller than in the United States. In the area of electricity transmission, however, the U.S.S.R. rate of progress has been appreciably faster than in the United States. The rate of progress in interconnection and coordination of individual supply systems appears to have been somewhat more substantial in the United States, but the U.S.S.R., given the apparent new know-how of extra high voltage transmission techniques, might be expected to move on very rapidly. On the whole, the pace of technological prog-

[30] "National Power Survey," vol. II, op. cit., p. 215.
[31] Ibid., p. 14.
[32] Ibid., p. 29.
[33] Ibid., p. 151.
[34] Ibid., pp. 214–274.
[35] Ibid., p. 29.
[36] Ibid., p. 14.
[37] Ibid., pp. 214–274.

ress in the field of electric energy supply has been substantial and very similar in both countries.

Readily available data do not permit accurate determination of the gap that still exists between the overall level of technology used in the generation, transmission, and distribution of electric energy in the U.S.S.R. and the United States. However, because more than 85 percent of Soviet electric power generating capacity has been installed since 1940—that is, the period of about equal rate of technological progress in both countries—we may presume that the gap, if any, is minimal and mostly concentrated in the area of conventional steam-plant generation and coordination of work of individual systems. As is shown in table 1, the proportion of the generating capacity in thermal plants in the U.S.S.R. is somewhat smaller than in the United States, but the proportions of the power generated from the two types of sources are much more alike in the two countries because the rate of hydropower capacity utilization is smaller in the U.S.S.R. than in the United States. (See table 2.) A rather superficial purview of the pertinent literature suggests, however, that apart from capacity utilization the present overall level of Soviet technology used in the area of hydropower generation alone is probably on par with or even slightly ahead of the United States. In the area of the energy transmission, because of recent Soviet progress in the extra high voltage, the lag, if any, is minimal too.

TABLE 2.—*Capacity utilization in Soviet and United States electric power industries—Average production of kilowatt-hours per kilowatt of installed capacity, selected years, 1940–63*

	1940	1950	1955	1958	1959	1960	1961	1962	1963
U.S.S.R.:									
All stations	4,316	4,651	4,570	4,388	4,473	4,381	4,421	4,478	4,431
Thermal	4,497	4,790	4,706	4,415	4,671	4,649	4,651	4,658	4,670
Hydro	3,222	3,943	3,863	4,279	3,747	3,444	3,612	3,863	3,610
United States:									
All stations	3,530	4,686	4,805	4,511	4,561	4,529	4,429	4,517	4,425
Thermal	3,318	4,484	4,876	4,451	4,589	4,534	4,460	4,534	4,490
Hydro	4,199	5,376	4,515	4,773	4,440	4,506	4,289	4,508	4,129
U.S.S.R. as percent of United States:									
All stations	122.3	99.3	95.1	97.2	98.1	96.7	99.8	99.1	100.1
Thermal	135.5	106.8	96.5	99.1	101.8	102.5	104.3	102.7	104.0
Hydro	76.7	73.3	85.6	89.7	84.3	76.4	84.2	85.7	87.4

Source: U.S.S.R., Promyshlennost' SSSR, 1964, p. 232; United States, Federal Power Commission.

The highest priority industry in the Soviet Union thus would seem to be on par with or very close to that of the United States in terms of both the rate of technological progress in the last 22 years or so and in terms of the overall level of technology presently in use.

(*5*) *Percentage distribution of steel-ingot equivalent tonnage of basic metals consumed in the economy*

In this indicator technological change is represented by increasing shares of aluminum and magnesium ("efficient metals") or, inversely, decreasing proportions of steel, zinc, copper, and lead.

As is shown in table 1, the U.S.S.R. made some progress in the use of the "efficient" metals over time, but it has been rather tardy, to

say the least. Moreover, the data for 1955–58 seem to suggest that there was some hesitancy or uncertainty concerning the direction in which the economy's metals policy should move. In the 22-year period the shares of aluminum in the Soviet total volume of basic metals consumption nearly tripled, from roughly 1 percent to about 3 percent, and that of magnesium about quadrupled, from five one-hundredths of 1 percent to not quite two-tenths of 1 percent. At the same time steel lost only 1.3 percentage points of its share, mostly since 1958; zinc lost about one-fifth of its prewar share; copper lost two-fifths of its; and relative use of lead was almost halved.

In the United States the relative use of aluminum increased almost 6 percentage points, or three times as much as in the U.S.S.R., and the relative use of magnesium gained from three one-hundredths of 1 percent to more than two-tenths of 1 percent.

Thus, in terms of changes in the pattern of basic metals consumption, technological progress has unquestionably been faster in the United States than in the U.S.S.R. The data do not permit a clear-cut pinpointing of when the United States was consuming the same proportions of the basic metals as the U.S.S.R. did in 1962. In terms of the relative importance of steel alone, however, we probably would have to go to the thirties or even the twenties. As shown in the table, in 1939 steel consumption represented 94 percent of total U.S. consumption of basic metals, but the shares of other metals were different from those in the U.S.S.R. in 1962.

(6) Changes in the use of steelmaking processes

In terms of the regime's priorities, the Soviet steel industry has probably ranked second only to the electric power industry. The progress in the Soviet steel industry, therefore, can be expected to exceed that of most other industries as well as the economy as a whole. The change in the process combination used in steelmaking is a fairly good, although not comprehensive, indicator of this progress. As in the case of changes in the technology of the electric power industry, however, the explanation of the nature of this progress requires a brief digression into the history.

Up to about 1905 the two principal processes used in steel production in all industrialized countries had been the Bessemer converter process and the open hearth processes (acid and basic). Of some importance also were crucible furnaces. The use of electric steelmaking processes was negligible. Since that time there have been substantial shifts in the relative use of these processes, largely in response to uneven trends in improvement, increasing demand for alloyed and low-carbon (high-quality) steel, supply and cost of scrap, and supply and cost of electric energy. In general, open hearth processes were becoming increasingly important up until about 25 years ago because they offered economies of scale in production and produced high-quality products; use of the Bessemer converter process has tended to decline rapidly except in countries with little scrap and a relatively large demand for high- and average-carbon steel; the relative use of electric proceses (both arc and induction) has tended to increase largely because of the growing supply of inexpensive scrap and electricity and the process' very good adaptability to the production of quality products; the use of crucible has practically ceased.

Since the middle 1950's, however, the oxygen converter, a major Austrian innovation developed in the late 1940's, has made headway.

Of the four processes listed in table 1, the steelmaking technological progress in the last 20 or 25 years is equated with changes in the relative use of oxygen converter and electrical processes, the latter, however, subject to certain qualifications.

As shown in the table, the Soviet relative use of electric processes constituted 5.9 percent in 1940 and increased to 8.9 percent in 1962, or 3 percentage points over the 22-year period. The use of oxygen converter, nonexistent in 1955, jumped to 2.2 percent in 1958 and 3.5 percent in 1962. The increase in relative use of both, the oxygen and electric processes, was made apparently almost fully at the expense of the Bessemer converter process, the use of which declined from 9.3 percent of the total in 1940 to 2.5 percent in 1962. The relative use of open hearths started to decline only after 1950, but in 1962 it was by three-tenths of 1 percentage point larger than in 1940.

Taking these data at face value, the Soviet steel industry has undoubtedly made some technological progress, but of a less spectacular nature than the industry's priority ranking might have led us to expect. Moreover, there seems to be a serious question as to whether the relative expansion of steelmaking by electrical processes and the reduction in the use of the Bessemer converter were economically justified, that is, whether they can be called "progress" at all. As noted earlier, steelmaking by electrical processes is an efficient method primarily in situations of an abundant supply of inexpensive scrap and cheap electricity. Neither of these situations prevailed in the U.S.S.R. at the time under review.[38] On the other hand, the reduction in the use of the Bessemer converter (the most inexpensive particularly in regard to capital cost, no fuel consuming process, but essentially applicable to the making of high-carbon steel only) is irrational in situations where there is scarcity of scrap, fuels, and capital and where there is a relatively large demand for high-carbon steel. All of these conditions prevailed in the U.S.S.R. during the period under review, and yet there was a drastic reduction in the use of Bessemer. West Germany, for example, which in many respects has scarcity relationships similar to those in the U.S.S.R., currently produces about 40 percent of its steel by means of the Bessemer process. It would seem that the Soviet substitution of electric processes for the Bessemer process was dictated by engineering (quality) considerations without regard to scarcity problems and that at least part of the substitution that took place between 1940 and 1962 constituted economic regress rather than process. There is no doubt, however, that the expansion in the use of the oxygen process represents unqualified progress.

In the United States, the relative use of electric steelmaking processes increased from only 1.9 percent in 1939 to 9.2 percent in 1962, a net gain of 7.3 percentage points over the 23 years. At least in part this expansion of steelmaking electroprocesses was prompted by continuing decreases in prices of scrap and electric energy relative to

[38] Relative to U.S. prices, the Soviet price of electric energy in 1955 was about 50 percent higher than the average prices for industrial products and services. At the same time, the electric power industry was one of the most profitable. In about 1961 the rate of profit of industry constituted about 40 percent of the cost of electricity. Cf. Planovoe Khoziaistvo, 1962, No. 1, p. 18.

other inputs used in steelmaking, particularly pig iron. The use of the oxygen process was nonexistent in 1955, as in the U.S.S.R., and only 1.6 percent of the total output was produced by the process in 1958, but by 1962 the percentage jumped to 5.6. In subsequent years the increase in the use of the process seems to have even accelerated. In 1963, according to American Iron & Steel Institute, it was used for 7.8 percent of the total U.S. steel output and in 1964 for 12.2 percent.

Judging by the changes in the use of the processes, the rate of technological change in the Soviet steel industry has lagged substantially behind that of the United States throughout the period and, probably, even more so in the most recent years. From what I know, this conclusion would not change if we were to base it on all innovations known to have been adopted in the two industries rather than the changes in the process use alone. With respect to most recent "other" steelmaking innovations Soviet industry would have to be credited with undoubtedly greater use of a new and reportedly very efficient continuous steel casting process and electroslag melting process.[39] These, however, are more than offset by numerous U.S. innovations in the area of steel rolling, particularly thin tinplate rolling, and the use of taconite processing in production of iron,[40] not used at all in the U.S.S.R.

(7) *Changes in metalworking technology*

Metalworking is another priority sector of the Soviet economy whose ranking has always been as high and recently even higher than that of the steel industry. The bulk of the metalworking sector is made up of machinery and related products industries, the economics and technology of which were the subject of my earlier study.[41] As pointed out in that study, technological progress in metalworking essentially consists of some 25 major innovations that are in process of introduction and various stages of diffusion.[42] Of these, the most representative for the overall progress is the rate with which metal forming operations have been substituted for metal cutting, or the increase in the use of metal-forming machinery relative to metal-cutting machines, and for the metal cutting field alone—the rate with which the numerically (usually tape) controlled machine tools have gotten into the use of the economy.

As shown in table 1, the relative use of the metal-forming machinery (machine tools) in the Soviet economy increased from 14.4 percent in 1940 to 16.9 percent in 1955, and 17.1 percent in 1958. Between 1958 and 1962, however, the relative use of metal-forming machinery was back at 16.9 percent, where it was in 1955. The total relative gain for the period as a whole was only 2.5 percentage points, and most of the recent years, in terms of this indicator, are marked by regress rather than progress.

The Soviet use of numerically controlled machine tools, judged by the data on output (item 7c), started in 1957 or 1958, and in 1962 the

[39] A simple process of melting under slag cover for high purity steel, competitive with electric vacuum melting but requiring reportedly only a fraction of the capital investment required for vacuum melting.

[40] Treatment of low-grade nonbearing rock by fine grinding and magnetic separation and agglomerating the magnetic portion into a high-grade blast furnace pellet feed by indurating. Comparable blast furnaces have produced 3,200 tons of iron per day utilizing a 100-percent taconite pellet and an estimated 1,600 tons utilizing a regular iron ore charge.

[41] The Soviet Challenge to U.S. Machine Building, op. cit.

[42] Ibid., app. D, pp. 62–68.

annual output constituted some 135 units. Between 1958 and 1962 the growth averaged some 80 percent per year.

In the United States the relative use of metal-forming machinery gained 3.5 percentage points through 1947 and 1962 alone, and the shift was evidently continuous thoughout the period. The commercial use of numerically controlled machine tools, in turn, started in about 1955. By 1958 the industry's annual output of such tools reached about 98 units, which subsequently grew at a rate slightly higher than in the U.S.S.R. even though the absolute level of the U.S. output was about 10 times larger than that of the U.S.S.R.

In terms of the use of the metal forming versus metal cutting machine tools, the rate of technological change in Soviet metalworking has lagged substantially behind the United States. In the metal cutting field alone, however, the rate of progress probably differed only insignificantly. On the whole, the U.S. rate of progress in the metalworking sector has undoubtedly been faster than in the U.S.S.R. throughout the period as well as in recent years although most of the U.S. superiority is concentrated in the field of metal-forming operations.

Basically the same conclusion must be drawn from the analysis of trends in the use of all of the 25 innovations analyzed in my earlier study, although some of the information presented there needs updating.

The data bearing on the overall level of technology used in the Soviet metalworking sector relative to the U.S. level seem to indicate a bizarre melange of backwardness, modernity, and in certain respects even superiority. In terms of the use of metal-forming versus metal-cutting machine tools and the average degree of advancement of metal-forming machines, present Soviet metalworking technology is probably about the same as it was in the United States in the twenties or early thirties. According to a Soviet source, in terms of the use of automated versus nonautomated equipment Soviet metalworking technology is about half as advanced as U.S. technology,[43] which is probably equivalent to a lag of some 20 to 25 years. In the area of metal-cutting operations alone the use of basically finishing (grinders, polishing, honing, etc.) versus "chip cutting" (lathes, slotters, etc.) machines also suggests a lag of some 20 to 25 years, but in terms of the use of numerically controlled machine tools the lag is probably not greater than 5 to 8 years; with respect to the use of electrical and electrochemical methods of machining Soviet technology is ahead of the United States.[44] The Soviet metalworking sector also surpasses the United States in the use of electroslag welding techniques.[45]

Although any generalization in cases like this is hazardous, it appears safe to assume that on the average the current Soviet metalworking technology used prevailingly in general or strictly "civilian" spheres of activity is about as advanced as the corresponding U.S. technology was during or at the close of World War II. In metalworking technology used prevailingly in the manufacture of military

[43] Cf. S. A. Kheinman, Organizatsiia proizvodstva i proizvoditel'nost' truda (Organization of Production and Productivity of Labor), Moscow, Gosplanizdat, 1961, pp. 95–106.
[44] See ibid.
[45] See "The Soviet Challenge to U.S. Machine Building," op. cit., p. 66.

hardware, however, the Soviet Union probably lags behind the United States only insignificantly and may surpass it in certain areas.

(8) Changes in the output of synthetic resins and plastics

The rationale of this indicator requires little comment. With phenomenal rapidity, synthetic resins and plastics, a group of a relatively few products that symbolize the concept of "chemization" of the economy, are beginning to play an eminent part of daily life in both the United States and U.S.S.R.

Starting with 16.4 thousand tons in 1940, the Soviet output of synthetic resins and plastics grew uninterruptedly at an almost constant rate of about 17 percent per year to 521.5 thousand tons in 1962. The U.S. output of these products was 106.5 thousand tons in 1939, about 6½ times as large as the Soviet output in 1940, and grew, also uninterruptedly at a virtually constant rate to more than 4 million tons in 1962, which was 7.8 times as large as the Soviet output in that year.

Judged by the growth in the output and, of course, the use of synthetic resins and plastics, the Soviet rate of technological progress has been almost as rapid as in the United States rate throughout the period, including recent years, but the Soviet overall level in 1962 was still on par with the U.S. level as far back as 1945–46, or roughly 20 years ago.

(9) Changes in the output of manmade fibers

This indicator, too, bears on the progress in "chemization" of the economies, and its significance requires no substantiation.

As shown in the table, in 1940 the Soviet output of manmade fibers was only 11,200 tons, equivalent to an annual output of a very small plant. In 1962, however, it was already 305,300 tons, an increase of 294,100 tons or 2,626 percent over 1940.

In 1939 the U.S. output of manmade fibers amounted to 200,000 tons, 18 times as much as the Soviet output in 1940, and by 1962 grew to slightly over 1.2 million tons, or 508 percent over 1939.

Manmade fibers constitute, thus, one of the two areas of technological progress in which the U.S.S.R. has clearly moved ahead faster than the United States throughout the period under analysis as well as in the last several years. The 305,300 tons of the fibers the Soviet industry produced in 1962, however, are roughly on par only with what the U.S. industry produced in 1940 or 1941, or 21 or 22 years earlier. Moreover, the gap between about 11,000 and 305,000 tons that took the Soviet industry 22 years to span was bridged by the U.S. industry in roughly 12 years, from 1927–28 to 1940, most of which were depression years.

(10) Changes in the industrial use of engineering and technical personnel relative to production workers

This is a rather indirect indicator of technological change. It is offered on the assumption that in the conditions of approximate optimal manpower use, increasing the level of technology should tend to increase the requirement for engineers and technicians relative to production labor because of the greater need for managing increasingly sophisticated machinery and equipment and for technological planning.

As is shown in the table, the ratio of engineering and technical personnel to production workers in Soviet industry increased between 1940 and 1962 by a mere half of 1 percentage point, from 9.7 to 10.2 percent. In the U.S. industry, however, the ratio increased in 20 years (1940–60) from 3.3 percent to 8.3 percent, that is, full 5 percentage points, or 10 times as much as in the U.S.S.R.

In terms of changes in the industrial use of engineers and technicians, the rate of technological change in the U.S.S.R. thus appears to have been substantially smaller than in the United States. As shall be pointed out in part VI of this study, however, there are serious questions as to the optimality of manpower use in the Soviet industry and, therefore, the data describing the changes in the use of engineering and technical personnel in the Soviet industry might not reflect the changes in technology with the same sensitivity as the data for the United States.

(11) Use of automatic data processing equipment (computers and punched card systems) in the economy

Automatic data processing (ADP) is one of the newest and, because of scope and economic consequences, undoubtedly the most profound technological innovation of the last 20 or so years. The first means of automation in data processing was provided by punched card systems developed prior to World War II, basically for the purposes of accounting and general recordkeeping only. The development and continuous improvements of computers since World War II have provided for fuller and economically more effective automation in traditional fields of accounting and general recordkeeping. These developments have also broadened the scope of ADP applications, namely, to the inventory control, data retrieval, production planning and control, scientific and engineering estimating of programs impractical to do before, forecasting, and process control. In short, automatic data processing today implies automatic recordkeeping, the capability to do most things in the best possible way, and to do these things by means of "automation."

This indicator, therefore, is one of the most important in our set because it bears on trends in the newest technology and covers an extremely wide scope. Unfortunately, because of data paucity it is not as revealing as we would like it to be. Yet it provides some basis for judgments in matters of concern here.

As shown in the table, in 1962 only some 6,200 punched card and computer systems were in use in the Soviet economy. The figure probably excludes equipment used by military establishments, but includes equipment in the use of other governmental agencies, particularly planning agencies. Of these 6,200 systems, some 15 to 20 percent (1,000 to 1,200 units) are estimated to have been computers and the rest punched card systems.

As of the end of 1963, the U.S. inventory of all computers and punched card systems, as in the U.S.S.R., net of military-operational and classified users of the Department of Defense, is estimated at a minimum of 50,000. Of these about 17,000 or 34 percent, were computers and 33,000, or 66 percent, punched card systems.

Thus, in about 1963 the U.S.S.R. use of all nonmilitary ADP equipment constituted only some 12 percent of the U.S. total. In the field of computer use alone, the ratio was even smaller—6 to 7 percent. In addition to a quantitative lag in use, Soviet equipment has also lagged considerably in quality. A group of U.S. scientists that visited Soviet computer manufacturing plants in late 1964 reported that in their judgment the computers manufactured in the U.S.S.R. at that time (1964) were two or three generations behind those manufactured in the United States. In view of this information, it seems safe to conclude that in terms of automatic data processing, and particularly electronic (computer) data processing, the rate of Soviet technological progress has been only a fraction of that in the United States and that the present overall level of Soviet data processing technology is at best as far behind the United States as most other sectors of the economy, and possibly even further.[46]

(*12*) *Changes in the modes of freight transportation*

Being only an occasional reader of the increasing flow of literature dealing with problems of efficiency in transportation [47] I realize that it is extremely hazardous to generalize about efficiency or inefficiency of any one transportation mode within a country, and an attempt at such generalization about whole transportation systems of countries as diverse as the U.S.S.R. and the United States should be out of the question. Because precisely such generalizations are the essence of this study, I can only try to be as noncontroversial as possible.

In making judgments about technological progress implicit in the data set forth in item 12 of table 1, I assume that although the relative use of various modes of freight transportation of a country at any given time depends on innumerable factors, the changes in their use in countries having a predominantly continental setting (such as the U.S.S.R. and the United States) are to a large extent a function of certain technological constraints and development. Given the present state of freight transportion technology, which in broad outlines is essentially the same as it was 25 or so years ago, a continental developing country which in the past relied almost exclusively on railroads would find it economically advantageous to build its new transportation facilities mix in such a way as to—

(*a*) Transport most short-haul freight, probably up to 200 or 300 miles one way, by trucks;

(*b*) Transport direct factory-retail store shipments requiring elaborate packing (such as needed for high-cost apparel, furniture, glass, porcelain, etc.) by specialized trucks;

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[46] One of the most important nonmilitary users of computers in the U.S.S.R. is probably the Novosibirsk Institute of Economy, headed by A. G. Aganbegian, corresponding member of the Soviet Academy of Sciences. We might presume, therefore, that Aganbegian knows about the state of affairs in the Soviet automatic data processing as much as anyone in the U.S.S.R. In his clandestine speech about the Soviet economy which became available long after the preceding evaluation of Soviet progress in automatic data processing was written, Aganbegian made several statements on problems of interest to this study, one of which bears on the state of affairs in automatic data processing. The statement is brief but eloquent and in the context of the present analysis needs no further comment. It reads as follows:

"The ZSU (Central Statistical Administration) with its method of processing statistical data is unable to carry out the task it should. It doesn't even have an electronic computer, nor does it have any intention of purchasing one" (cf. the ASTE Bulletin, vol. VII (summer 1965), p. 4).

[47] Cf., e.g., Gary From, ed., Transport Investment and Economic Development, the Brookings Institution, transport research program, Washington, D.C., 1965.

(*c*) Transport perishable goods by trucks and/or air;

(*d*) Transport emergency shipments of spare parts for industrial equipment, medicine, etc., by air and/or trucks depending upon distances involved;

(*e*) Transport all line-haul oil and other liquefiable bulk commodities by pipelines and short distance by specialized trucks;

(*f*) Transport all bulky and time-insensitive products via waterway, provided that natural conditions make their use economical.

Compared with railroad transportation, the use of assumed nonrailroad facilities in the delineated areas would be less costly (less resource requiring) to the economy because of either shorter distances the freight would move, or because of fewer loadings and unloadings, a smaller rate of spoilage and waste, increased speed of deliveries. higher productivity of labor and, in most instances, reduced capital cost.

It should be obvious that, on one hand, the incidence of such technologically rational needs for nonrailroad transportation facilities, for example, automotive, pipelines, airways and waterways, will be the greater the more developed is the economy; and, on the other hand. the rate of an economy's technological progress will be the greater the faster it is responding to these needs.[48]

As is shown in the table, the share of railroads in all Soviet freight traffic by public means (we do not know of any nonpublic freight transportation facilities in the U.S.S.R.) decreased from 85.1 percent in 1940 to 77.8 percent in 1962, or 7.3 percentage points. Most of this decline occurred after 1955. The decline in the relative importance of railroads is matched by gains of, in their order of magnitude, automotive freight carriers, pipelines, waterways, and some airways not recorded in the table. The share of automotive carriers increased from 1.8 percent in 1940 to 5.3 percent in 1962, a net gain of 3.5 percentage points made more or less gradually throughout the period. Oil pipelines gained 2.7 percentage points in the period, most of them since 1955. The share of inland waterways increased 1.1 percentage points over the period as a whole and even more, 1.5 percentage points, between 1958 and 1962. Soviet freight transportation by air is also growing, but in 1962 it still constituted less than one-twentieth of 1 percent of the total.

All of these changes, whether looked upon from an a priori point of view of the rapid growth of the economy or, particularly, from the point of view of most of the apparent needs or potentialities for changes, indicate only a very modest progress, and it is questionable whether the relative expansion in automotive freight transportation represents genuine progress or only a necessary adjustment to changed environment. Thus, for example, in 1962 Soviet railroads still carried almost 75 percent of all line-haul ton-miles of oil, pipelines about 22 percent, and waterways the rest. The average length of freight haul by trucks, in turn, increased from 6.2 miles in 1940 to 7.6 miles in 1962;

[48] It will be noted that the technologically rational modes of transportation for the various types of cargo set forth above are broadly similar to those envisaged by John R. Meyer and associates as probably the lowest cost combinations for a "rational (U.S.) transportation system." Cf. John R. Meyer et al. The Economics of Competition in the Transportation Industry, Harvard University Press, Cambridge, Mass., 1959, ch. VI.

that is, about 23 percent, which probably was just enough to cover enlarged urban territories.

There are no statistics on all freight transportation in the United States. In view of the relative unimportance of local freight transportation in the total of the U.S.S.R. (deemed to be about equal to the share of trucks, 1.8 percent in 1940 and 5.3 percent in 1962), a comparison of Soviet data on all freight traffic with the data on U.S. intercity freight traffic should not produce grossly erroneous results. The comparison as well as some other pertinent information suggests that the designation of the apparent Soviet technological progress in the area of freight transportation as modest is appropriate also in relation to the United States.

As shown in the table, the share of railroads in the total U.S. intercity freight transportation increased 2.9 percentage points between 1939 and 1947, from 62.3 to 65.2 percent. Since 1947, however, there has been a continuous decline: 15.7 percentage points between 1947 and 1954, 2.9 percentage points between 1954 and 1958, and 2.9 percentage points between 1958 and 1962. The decline in the railroads' share between 1954 and 1962 would probably have been substantially greater, possibly twice the size of the actual, had the railroads not resorted to technological modernization, largely in the form of advancing larger, lighter, and highly specialized cars, automatic (some computerized) control of classification yards, centralized traffic control, mechanization of way maintenance and, of course, the most important of all, the piggyback service.[49] Back in 1954 only a negligible number of all revenue car loadings were piggybacks. In 1962 they constituted 2.4 percent of the total and, in 1964, 3 percent. With the probable exception of centralized traffic control and size of cars, all of these innovations in the U.S.S.R. are still in an "embryonic" state of use. The Soviet railroads use substantially more electric traction power (electrification) than used in the United States, but this, to a large extent, is offset by greater dieselization of U.S. railroads in general, and the use of new superpowerful diesel-hydraulic engines in particular.

The share of U.S. inland waterways declined 3.3 percentage points from 17.7 percent in 1939 to 14.4 percent in 1947, but by 1954 the waterways regained one-third of this loss and since then have more or less maintained the status quo apparently because of, mainly, the opening of the St. Lawrence Seaway and such improvements as the increased sizes and speeds of barges and towboats and the mechanization of loading and unloading.

The U.S. modes of freight transportation, the relative uses of which increased, are the same and, with the exception of the magnitude of gains, in the same order as in the U.S.S.R. U.S. automotive freight transportation increased from 9.8 percent in 1939 to 23.6 percent in 1962. A net gain of 13.8 percentage points or almost four times as much as in the U.S.S.R. In addition, the U.S. trucking industry has probably made much faster and more extensive internal technological progress in such areas as large detachable vans and trailers

[49] Piggyback service consists of using a highway tractor and trailer for picking up and delivering freight and transferring the trailer to a railway flatcar for line-haul transportation between urban centers.

and specialized unit bodies than the U.S.S.R. trucking industry has made. The share of U.S. freight transportation by means of pipelines (largely oil), in turn, increased from 10.2 percent in 1939 to 16.9 percent in 1962, or a total of 6.7 percentage points gain over the 23-year span, which is almost two and a half as much as in the U.S.S.R. In addition, the U.S. pipeline industry has undoubtedly moved faster than the U.S.S.R. to large diameter pipelines, an internal technological development in the industry. Finally, the U.S. airways managed to get more than eight-tenths of 1 percent of the total freight business by 1962,[50] in contrast to only one-twentieth of 1 percent in the U.S.S.R.

On the basis of all this information it seems fair to conclude that the rate of technological progress in the Soviet freight transportation industry over the period from 1940 to 1962 as a whole was only one-third to one-half of what it was in the United States at the time. Since 1958, however, it has probably lagged only insignificantly, perhaps by 20 to 25 percent.

The available data do not permit an accurate determination of the time when the United States used a freight transportation technology similar to that presently used in the U.S.S.R. Ignoring the use of air transport and extrapolating the rates of change between 1939 and 1962 backward suggest that it was in the late 1920's.

(13) Changes in the modes of intercity passenger transportation

Using, by analogy to freight transporation, probable cost, speed, flexibility, and convenience as yardsticks (in comparison with practically 100 percent reliance on railroads), the progressive elements in this indicator are assumed to be the decreasing share of railroads and, conversely, the increasing shares of automobiles and airways. Use of waterways for passenger transportation is difficult to evaluate in this respect. Because of similarity of trends in the use of this mode in two countries however, it might be disregarded.

However surprising it might sound, U.S.S.R. technological progress in the area of passenger transportation has been at least double of what it has been in freight transportation, and possibly higher. As shown in the table, the Soviet railroads carried 95.3 percent of all passenger traffic in 1940, but by 1962 their share declined to 79.3 percent, or full 16 percentage points. The share of inland waterways also declined from 4.5 percent in 1940 to 2.5 percent in 1962. The combined loss of the 18 percentage points in the shares of railroads and inland waterways accrued as gain, split almost equally between automobiles and air transport; the share of the U.S.S.R. automobile passenger transport increased from only nine-tenths of 1 percent of all intercity passenger miles in 1940 to 9.7 percent in 1962, and the share of air transport from about two-tenths of 1 percent in 1940 to 8.5 percent in 1962.

The changes in the modes of all intercity passenger transportation in the United States have basically been in the same direction as in the U.S.S.R. but much less pronounced. By 1939 the share of U.S. railroads constituted only 9.9 percent. Due obviously to World War

[50] Cf. Historical Statistics of the United States, op. cit., table Q1–11, p. 421 and Statistical Abstract of the United States, 1964, table 773, p. 570.

II inadequacies in supply of automobiles, it increased to 14.2 percent by 1947, but in subsequent years it continued the pre-World War II trend of decline and in 1962 reached the level of 2.5 percent of the total. The share of inland waterways also decreased, from seven-tenths of 1 percent in 1940 to about three-tenths of 1 percent in 1962. The relative aggregate loss of the two modes of passenger transportation over the entire 1939–62 period was thus 7.8 percentage points, slightly less than half of that in the U.S.S.R. between 1940 and 1962. The gainers were automobiles, the share of which increased from 89.1 percent in 1939 to 92.5 percent in 1962, or 3.4 percentage points; and airways, from only three-tenths of 1 percent in 1939 to 4.7 percent in 1962. The share of intercity passenger transportation by means of automobiles in the United States thus increased only about one-third as much as in the U.S.S.R. and that of airways only about half as much.

The apparent disparity between the U.S.S.R. and U.S. rates of technological progress in the area of passenger transportation would probably be somewhat narrower if the analysis were broadened to cover all the innovations in the field rather than focus on broad changes in the systems alone, but it seems unlikely that the discrepancy could be entirely eliminated. Needless to say, this outcome is the result of numerous factors, but primarily of the Soviet start at a very low level in the base period and the large spillover from the advancements in military aviation.

As in the case of freight transportation, we may only guess as to when U.S. passenger transportation technology was on a par with that used in the U.S.S.R. in 1962 or today. U.S. railroads carried about 75–80 percent of all intercity passenger traffic sometime in the first quarter of this century. At about the same time, U.S. automobiles probably carried about 10 percent of the traffic. U.S. inland waterways had a 2.5 percent share of the total passenger transportation at the end of the 19th century. U.S. airways will probably carry some 9 percent of total intercity passenger traffic 15 or 20 years from now. The 1962 absolute level of Soviet passenger air transportation (passenger-miles flown by air), however, was about on par with the United States of early 1950's.

(14) Use of telephones

Although in the United States we tend to associate the use of telephones with home convenience and high standard of living, the consequentiality of telepone use for productivity and overall technological advancement of an economy can hardly be questioned. In fact, progress in the use of telephones by an economy might be considered as the best single indicator of progress in the whole field of communications, which, in turn, is frequently equated with the progress of the whole economy. Although the Soviet data on the use of telephones are still shrouded with secrecy, the analysis of whatever is available permits valid conclusions on questions of interest to this study.

Item 14 of the table lists the data on the Soviet use of the telephones which are under the jurisdiction of the Ministry of Communications. This Ministry administers the "civilian" network only. Hence, the figures posted in the table do not include the telephones used by the armed forces, and, most probably, those used by the party, parts of the Government, and the police.

The use of the telephones under the jurisdiction of the Ministry of Communications increased from 1.2 million units in 1940 to roughly 3.2 million in 1962, or by 162 percent. The average rate of growth in the use of these telephones over the 22-year period was thus about 4.5 percent per year. The rate of growth in the use of all telephones in the U.S.S.R., however, must have been smaller than 4.5 percent, possibly only half of that. The reason for this is that in 1963 the telephones under the jurisdiction of the Ministry of Communications constituted only 52.7 percent of the total excluding the military uses.[51] Since it is reasonable to assume that in 1940 the "civilian" network was a substantially smaller proportion of the total than in 1963, the rate of growth of the total must have been smaller than that of the "civilian" portion.

The use of all telephones in the United States increased from 20.8 million units in 1939 to almost 81 million in 1962, or by 289 percent. The increase is equivalent to an average rate of growth of 6.1 percent per year, or roughly 35 percent higher than the growth rate of Soviet "civilian" use and probably more than twice as high as the Soviet use of all telephones.

The increase in the gap between the Soviet and United States overall levels of technology attributable to differential rates of growth in communication, however, is probably even greater than the data on the use of the telephone suggest. By now, for example, automatic telephone dialing embraces almost three-fourths of the United States, but in the U.S.S.R., according to recent visitors' reports, quite a few Moscow suburbanites still cannot reach even Moscow directly. A similar relationship prevails in the use of teletyping, and other means of communications.

Judging by the use of telephones alone the present overall level of technology in the Soviet economy is probably on par with the level of U.S. technology in the late thirties.

(15) Changes in mechanization and "chemization" of agriculture

Although recent technological progress in agriculture has probably been as varied as in industry, most of the innovations in agriculture in the two countries can be classified as either "mechanization" or "chemization." The data on changes in the use of tractors, grain combines, and motortrucks per 1,000 acres af harvested cropland listed in item (15) of the table purport to indicate the changes in mechanization and the data on the use of primary commercial fertilizer (100 percent nutrient content)—the advances in "chemization." The measures, as in most previous cases, are crude, but not void of meaning.

The use of tractors, grain combines, and motortrucks in Soviet agriculture increased in the 22-year period by, respectively, 74, 98, and 169 percent. The average increase for the three items was 114 percent, which implies an average rate of growth of about 3.5 percent per year. In the 1958–62 period alone, the three items of mechanization increased by, respectively, 20, 40, and 23 percent, on average about 28 percent, which is equivalent to a growth of about 6.3 percent per year.

[51] Narodnoe khoziaistvo, 1963, p. 438.

The use of commercial fertilizer in Soviet agriculture increased over the 22-year period by 185 percent, or, on average, about 4.9 percent per year. In 1958–62 the increase was only 10 percent, or, on average, 2.5 percent per year.

The growth in mechanization of U.S. agriculture in the 23-year period was: 264 percent in tractors, 509 percent in grain combines, and 216 percent for motortrucks, or, on the average 330 percent. This is equivalent to an average growth rate of 6.5 percent per year, almost double the Soviet rate. Between 1958 and 1962, however, the use of the three mechanization indicators in U.S. agriculture increased on the average only by 7.4 percent, that is, about one-fourth of the increase in the U.S.S.R.

The use of commercial fertilizer in U.S. agriculture in the 23-year period increased by 496 percent. This is equivalent to an average growth rate of 8.1 percent per year, which is about 65 percent higher than in the U.S.S.R. In the 1958–62 period alone, however, the use of commercial fertilizer in U.S. agriculture increased by 38 percent, or almost four times as much as in the U.S.S.R.

The implications of these comparisons require hardly any comment. Although in isolation the technological progress in agriculture implied in the Soviet data might be quite impressive, it is less than modest in comparison with the United States. Moreover, it seems fairly certain that the gap between the Soviet and the U.S. rate of technological progress in agriculture has actually been even greater than these comparisons indicate. The reason for this is that in addition to the increasing quantitative gap in the use of various items of mechanization in Soviet agriculture shown in the table, there has probably also been an increasing gap in the quality and complementarity of the items used. Furthermore, although no comprehensive analysis has been made to that effect, indications are that Soviet agriculture has also lagged behind the United States in the use of irrigation, seed selection, and crop protecting chemicals and insecticides.

Judging by the data given in table 1 alone, the overall level of mechanization of Soviet agriculture in 1962 was about on par with the U.S. agriculture of early 1930's, and in terms of the use of commercial fertilizer on par with the United States of about 1945.

This concludes the review of the indicators in detail. Let us turn now to what they show in the aggregate.

COMPARISON OF TECHNOLOGICAL PROGRESS: SUMMARY VIEW

In order to generalize about the Soviet overall rate of technological progress relative to that of the United States during the 1939/40–1962 period as well as during some of the most interesting subperiods from an analytical point of view, I first determine the U.S.S.R./U.S. relative changes in the individual indicators and then aggregate them into overall averages. For purposes of aggregation I weigh the U.S.S.R./U.S. relative changes in "weightable" individual indicators with relative potential savings of labor (man-years) per unit change in the respective indicators in the U.S.S.R. The data underlying these weights may be found in appendix B. The results of the calculations for the 1939/40–1962 and 1950–62 periods, which I consider to be analytically most important, are presented in table 3.

TABLE 3.—*Aggregation of individual indicators of Soviet technological change relative to the United States into an overall average, 1939/40–62 and 1950–62*

Item No.	Indicator	Weight assigned to the indicator (percent)	Change from 1939/40 to 1962				Change from 1950 [1] to 1962			
			U.S.S.R.	United States	U.S.S.R./U.S.	Contribution to the relative aggregate change (col. 1× col. 4)	U.S.S.R.	United States	U.S.S.R./U.S.	Contribution to the relative aggregate change (col. 1× col. 8)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*1	Increase in the share of natural gas in the composition of fuels consumed in the economy, percentage points	6.0	10.3	21.0	49	2.940	9.8	12.6	78	4.680
2	Increase in the share of oil in the composition of fuels comsuned in the economy, percentage points	4.0	10.6	10.9	97	3.880	10.9	4.3	253	10.120
3	Decrease in the share of inefficient ("Other") fuels in the total consumed in the economy, percentage points	3.0	8.6	4.0	215	6,450	6.8	1.6	425	12.750
*4	Increase in electric energy input per production worker in industry, percent	16.0	328.0	329.0	100	16.000	230.0	191.0	120	19.200
5	Increase in use of mechanical power per production worker in industry, percent	9.0	232.0	329.0	70	6.300	203.0	191.0	106	9.540
*6	Technological improvements in generation and transmission of electric power	.3			100	.300			100	.300
*7	Increased share of oxygen process in steelmaking, percentage points	.7	3.5	5.6	63	.441	3.5	5.6	63	.441
*8	Increased share of aluminum in total basic metal consumption, percentage points	1.4	2.0	5.9	34	.476	1.0	2.9	34	.476
*9	Increased share of metal forming machines in total machine tool stock, percentage points	2.0	2.5	4.6	54	1.080	1.3	3.5	37	.740
*10	Increased use of N/C and other new processes in metalcutting, percent	1.5			100	1.500			100	1.500
*11	Increased use of synthetic resins and plastics, percent	.7	3,075.0	3,703.0	83	.581	635.0	647.0	98	.686
*12	Increased use of manmade fibers, percent	.7	2,626.0	508.0	516	3.612	1,239.0	207.0	599	4.193
13	Increased share of automobile freight traffic in the total, percentage points	3.0	3.5	13.8	25	.750	2.5	9.0	28	.843
*14	Increased share of pipelines in total freight traffic, percentage points	6.0	2.7	6.9	39	2.340	2.8	3.8	74	4.440
*15	Increased use of automatic data processing, hundred units	9.5	620.0	5,000.0	12	1.140	620.0	5,000.0	12	1.140
16	Increased use of tractors, combines and trucks in agriculture, percent	18.0	214.0	429.0	50	9.000	178.0	166.0	107	19.260
*17	Increased use of fertilizer in agriculture, percent	18.0	185.0	496.0	37	6.660	164.0	218.0	75	13.500
	Overall relative change, U.S.S.R. as percent of United States, based on all indicators					63.0				104.0
	Overall relative change, U.S.S.R. as percent of United States, based on * indicators (assumed to be "contemporary" innovations)					59.0				82.0

[1] For U.S. 1947–54 average. Source: App. B (weights) and table 1.

Before I turn to the interpretation of these results, four points should be noted.

First, as I noted in the discussion of methodology, it would be preferable to use weights based on total cost savings per unit change in the use of the innovations because such weights would reflect total factor savings to the economies. This was not possible because of lack of value data in the detail needed for such calculations. The use of weights based on labor savings assumes that the principal savings resulting from technological change are in the form of labor savings and that capital savings are in fixed proportion to the labor savings.

Second, the weights I use are based on the U.S.S.R. estimates of labor productivity increases resulting from the introduction of the respective innovations and on the data on actual employment in pertinent segments of the Soviet economy in 1959. The productivity data used for the purpose are mostly estimates of the Soviet design and projectmaking (A. D. Little type) organizations and, therefore, are likely to indicate potential increases, rather than actual. In making use of these estimates I assume that the actual savings would be smaller than potential, but the proportions would be about the same.

Third, the reliance on the Soviet weights alone makes the comparison very rough. For somewhat more refined conclusions it would be desirable to weight the relative changes in the indicators also with comparable U.S. weights and then take the geometric mean of the two. With the time available I could not do this. I reason, however, that it would also be necessary to make adjustments for quality differences between each country's respective innovations. Judging by the differential productivity levels of Soviet labor in various sectors of the economy relative to the United States and the respective relative changes in the technological progress, the use of U.S. weights would probably result in somewhat higher overall rate of Soviet technological progress relative to the United States than the Soviet weights, but the adjustments for quality would certainly set the overall relatives back to or close to what we get if we use the Soviet weights only.

Fourth, the aggregation excludes the "nonweightable" indicators, or rather, indicators that are difficult to weight; notably, the indicators of changes in the use of engineers per production worker, changes in the use of telephones, and changes in the modes of passenger transportation. The exclusion of changes in the use of engineers obviously favors the U.S.S.R. in the comparison, but not much. The exclusion of changes in the use of telephones and changes in the modes of passenger transportation, however, is by and large inconsequential because the differential trends in the two countries must to a large extent cancel out.

Bearing these qualifications in mind we may turn to the results. As shown in the bottom portion of the table, when all "weightable" indicators are used in the comparison, the overall rate of Soviet technological progress over the 1939–40 to 1962 period as a whole appears to have been only about 63 percent of the U.S. rate of progress, and in the 1950–62 period about 104 percent, or roughly the same as in the United States. When the comparisons are based on the indicators marked by the asterik, which are considered to be more or less "contemporary" innovations (or, rather, those that do not appear to have

reached a "saturation" point in the United States by the middle 1950's or so), the Soviet overall rate for the 1939–49 to 1962 period drops to about 59 percent of the U.S. rate and for the 1950–62 period to roughly 80 percent.

As is clearly evident in this summary table the improved performance of the Soviet economy relative to that of the United States in the 1950-62 period, in terms of the diffusion of all innovations as well as the "contemporary" ones, must be attributed partly to a greater effort to innovate, and partly to a smaller rate of change in the United States since about the middle 1950's compared to the decade following World War II.

The only areas in which the rate of Soviet technological change in the 1939–40 to 1962 period as a whole outpaced the United States are the substitution of coal for wood and other inefficient fuels, the rate of growth in the output of manmade fibers, and the changes in the modes of passenger transportation. The first and the last of these were clearly "mature innovations" in the United States by the late 1940's or even earlier, and the second by the end of the 1950's.

The areas in which the Soviet economy seems to have made the greatest substantive ("civilian") technological strides, although not greater than the United States, are the energy field, including the generation and transmission of electricity, and metal-cutting technology. In all other areas Soviet technological progress has been modest. This is obviously a reflection of the overall Soviet strategy of industrialization that emphasized industrial production, particularly metalworking, without much regard to quality and cost and with considerable neglect of other areas of economic endeavor, particularly agriculture.

The most apparent formal reasons for the decline in the U.S. rate of "civilian" technological progress since the middle of the 1950's are obviously the "maturity" of the "oldtime" innovations and insufficient makeup by the new innovations.

In 1947–58, the principal vehicles of the U.S. "civilian" technological change were the displacement of coal by gas and oil, the mechanization in industry and mining (as shown by the consumption of electric energy and installed horsepower per production worker), the substitution of aluminum for steel and copper, the substitution of metal-forming operations for metal cutting in the metalworking sector, the substitution of manmade fibers for cotton and wool, the expanded use of synthetic resins and plastics, the substitution of trucks and pipelines for railroads in freight transportation, the extremely rapid expansion in mechanization, and use of fertilizer in agriculture. All of these changes grew throughout most of the 1947–58 period either exponentially or at only moderately diminishing rates.

In the 1958–62 period, however, all of the preceding innovations (except the use of plastics) grew at rapidly diminishing rates, if at all. The principal vehicles of technological change in this period, mostly introduced only in the fifties, are the use of computers (affecting data processing and permitting "computerized" automation in industries where formerly "instrumentation" automation was used), the use of numerically controlled machine tools in metalworking, the continued expansion in the use of plastics and petrochemicals, and

the use of insecticides in agriculture. All of these new principal vehicles of technological change seem to have grown in the recent period more or less exponentially, but their aggregate factor saving impact on the economy has undoubtedly been smaller than that of the changes in the earlier period.

It is outside the scope of this study to go beyond the assembled statistical evidence and speculate about the substantive reasons for the decline, such as disproportionalities in R. & D. expenditures, inadequacy of research manpower working in the field of civilian technology, inadequate transferability of innovations from defense R. & D. to civilian use, inadequacy of financial incentives, and the like.

The most obvious implication of the slower overall rate of technological progress in the U.S.S.R. than in the United States between 1939–40 and 1962 is that in 1962 the overall relative level of Soviet "civilian" technology was further behind the United States than in 1940. As has been pointed out in the detailed discussion of the indicators, this 1962 overall level, judging by the prevailing scope in the use of most important innovations, was about the same as in the United States between 1939 and 1947, or about the time of World War II.

All of these findings, even with all the qualifications we can reasonably make, are surprising to say the least. They are especially surprising for the U.S.S.R. It has generally been believed that because of the lower level of technology in the U.S.S.R. to begin with, the faster rate of capital formation (on the average almost three times as fast as in the United States), the centralized planning of investment, the mostly technical background of managerial "cadres," and the practically unlimited opportunities for borrowing advanced foreign technology at little or no cost, the Soviet technological progress must have been faster than in the United States. This is not true.

IV. Comparisons of Factors Productivity

THE DATA AND SOURCES OF INFORMATION USED

The comparisons of factor productivity growth in the two economies are based essentially on the data for the respective countries' gross national product (GNP), civilian employment, and gross fixed business capital stock.

For the U.S.S.R. I use:

GNP—composite U.S. style index derived from Stanley H. Cohn's (1950–62) extended to 1940 in accordance with Bergson's. This combination introduces some inaccuracy because Cohn's index refers to values in 1955 ruble factor cost and Bergson's 1937 ruble factor cost. Judging by the 1950–55 overlaps in the two indexes, however, the inaccuracy is not greater than a few percentage points for the 1940–62 period as a whole. Such magnitude could not materially affect the analysis.

Employment (civilian)—Soviet official data.

Gross fixed business capital stock—Soviet official ("postevaluation") data for productive capital stock in constant (1955) prices from which I subtracted the value of animal herds.

The use of gross fixed business capital stock data calls for two comments. The first pertains to the rationale of using fixed business capital stock data rather than data on all capital stock, which is usually preferred by economists; and, second, the rationale for using gross estimates of fixed business capital rather than net—also usually preferred by economists.

My decision to use fixed business capital stock data rather than data on all capital stock of the economy is based upon consideration of presumed quality of the data and appropriateness of all capital stock data for a productivity analysis. The difference between the fixed business capital and all fixed capital represents the value of residential construction and capital used by governments and other institutions for nonproductive purposes. I believe, first of all, that estimates of all capital stock in any economy, including that of the U.S.S.R., are much less accurate than estimates of fixed business capital and, therefore, the latter is preferable to use. Secondly, residential construction capital and other capital used for nonproduction purposes contributes little or nothing to an economy's growth in productivity as we calculate it and, therefore, is not appropriate.

The reasons for using gross (of depreciation, of course) rather than net estimates of fixed business capital stock, in turn, are four:

(1) The gross estimates reflect the actual (physical) use of plants and equipment much more accurately than net estimates because the latter are largely accounting entities.

(2) The gross estimates are easier to handle analytically, particularly in regard to convertibility, because they are not complicated by the subtraction of depreciation charges, which rarely are the same in different countries.

(3) Although the use of net estimates, which reflect capital in use in a way that is closer to comparable quality standards could give a potential advantage, different rates in quality changes of capital in different economies and distortions of differential depreciation rates make these potential advantages highly unrealistic.

(4) The gross estimates are more readily presentable because the net estimates for the U.S.S.R. would have to be derived from the gross and inadequate additional information, which would introduce additional errors into the analysis. The U.S.S.R. does not publish the net estimates although the Central Statistical Administration makes them.

For the United States, in turn, I use:

GNP (actual)—estimate of the U.S. Department of Commerce, Office of Business Economics (revised in August 1965).

GNP (potential)—my own estimate based on actual GNP and ratios of civilian employment to the civilian labor force (potential employment). This estimate, derived by simple (linear) adjustment of actual GNP for unemployment without any correction for economies or diseconomies of scale, differentials in productivity of employed and unemployed manpower, capital and land, is obviously very crude. The purpose for using it, and derivatives based on it, is solely to account for cyclical fluctuations in U.S. economic activity. However, since the analytical usability of the estimate is rather limited, I use it along with rather than in place of the estimate of the acual GNP. The estimate of the GNP for the U.S.S.R. is, of course, assumed to represent both actual and potential.

Actual and potential unemployment (labor force)—estimates as reported in the Economic Reports of the President and Historical Statistics of the United States.

Gross fixed business capital stock—two estimates of U.S. private fixed business capital stock prepared by OBE in 1954 prices, one assuming Bulletin F service lives of the assets and another assuming service lives 20 percent longer, each of these estimates adjusted to make them conceptually comparable to the U.S.S.R. estimates of "productive capital" net of the value of animal herds by the addition to the OBE estimates of capital used and leased by government for commercial or production type of activity and the subtraction of capital of private nonprofit institutions. Bulletin F, it will be noted, is an Internal Revenue Service manual designed to facilitate calculation of business depreciation charges for tax purposes and used up to the end of 1962.

For aggregation (weighting) of labor and capital inputs into the aggregated (total) factor inputs, I use estimates of average labor and nonlabor shares (proportions) in national income in respective countries—70–30 in the U.S.S.R., and 75–25 in the United States.

For conversion of the Soviet ruble values into U.S. dollars I use Bornstein's cross-weighted purchasing power ratios rather than "official" exchange rates.

Finally, for purposes of partial tie-in with the analysis of technological progress set forth in the preceding part and for references in part VI of this study, in the analysis of factor productivity I use also each country's data on consumption (input) of mineral fuels and wood fuel, consumption of basic metals, and input of freight transportation.

CONSISTENCY OF THE DATA USED

In a study based on such a great variety of data as I have assembled, it seems appropriate to wonder about the adequacy of the Soviet and at least some of the U.S. data for the type of analysis I undertook.

The general limitations of Soviet statistics have been described in numerous familiar studies specifically concerned with this matter, and there is no need here for detailed reiteration of the conclusions stated therein. Based on the conclusions of these studies and on my own general observations, my view of the data which I use in this analysis is as follows:

(*a*) Soviet employment data (as is the case of most of the data used in the analysis of technological progress) are regularly reported in physical units of measure, and inaccuracies in these data, if any, are probably not greater than in the corresponding U.S. data.

(*b*) The estimates of Soviet GNP have been prepared in the United States according to the U.S. concept, but based on the Soviet data, and, therefore, are only as good as the underlying data and the judgments of the scholars who made the estimates. There is no reservation with respect to the judgments of the scholars who prepared the estimates but the adequacy of the underlying data has never been ascertained.

(*c*) The data on Soviet gross fixed business capital stock which I use come from a relatively new official series based on 1959 and 1962 inventories of capital assets in the U.S.S.R. and investment data. I have a feeling that this series represents the best major statistics ever

produced in the U.S.S.R. However, despite my effort to make the necessary adjustments in these statistics as accurately as possible, I probably succeeded in only a crude sense. As noted, I equate the Soviet concept of productive capital stock (proizvodstvennye osnovnye fondy) net of the value of animal herds with the estimates of the U.S. private fixed business capital less the capital used by all private nonprofit organizations (largely private schools, churches, hospitals, etc., because capital of such organizations is classified in the U.S.S.R. as nonproductive) plus capital owned or used by Government in business-type enterprises (classified in the U.S.S.R. as production capital). This is as close an approximation as can be made, but the two concepts are not quite the same.[52] Of several elements of incomparability, the most important is that the Soviet estimate excludes capital used by such Government institutions as banks and insurance agencies, and such municipal services as public laundries. All of these are largely private businesses in the United States, and their capital is included in the U.S. estimates of business capital. It is assumed that these omissions in the U.S.S.R. estimate are matched by exclusion of capital used by such U.S. "nonprofit" organizations as farmers' cooperatives, which conduct ordinary business, and whose type-likes are included in the Soviet estimate.

Another uncertainty with respect to the use of the capital data, although small, stems from our imperfect knowledge as to which of the U.S. alternative estimates (assumed service lives) describes more accurately the actual use of capital in the U.S. economy and, hence, is more appropriate for the comparison with the U.S.S.R. On the whole, the estimate for the United States which assumes Bulletin F service lives of the assets shows a faster growth of the U.S. fixed business capital, and this results in a somewhat lower growth of total factor productivity as well as a higher ratio of Soviet fixed business capital relative to the United States than does the estimate which assumes service lives 20 percent longer than Bulletin F.

Up to about 4 years ago, economists in the United States had generally assumed that the average service lives of various capital assets were about equal to those postulated in so-called Bulletin F. Bulletin F assumed that business capital equipment was used 16 years in farming, 17 years in manufacturing, and 13 years in industries other than manufacturing and farming; and nonresidential structures were used 90 years in farming, 40 years in manufacturing, and 36 years in industries other than manufacturing and farming.[53] Since 1962, however, apparently under the impact of arguments that have led to the cancellation of the provisions of Bulletin F, there has been an increasing tendency to assume the service lives even shorter than postulated in Bulletin F.

In using the two estimates I assume, however, that the average service lives of fixed business capital assets as postulated in Bulletin

[52] Extensive discussions of the Soviet capital concepts and the 1959 and 1962 revaluation programs may be found in Norman M. Kaplan's chapter "Capital Stock" in A. Bergson and S. Kusnets, ed., Economic Trends in the Soviet Union, Harvard University Press, Cambridge, Mass., 1963, pp. 96–149, and in "The Soviet Capital Stock Inventory and Revaluations" by Adam Kaufman in Guidelines for the Improvement of Wealth Data and Estimates, Report of the Wealth Inventory Planning tudy, vol. II. The George Washington University, 1964 (mimeographed).

[53] Survey of Current Business, November 1962, table 7, p. 28.

F most probably constitute a minimum and that it is also probable that they might have been up to 20 percent longer. This seems sensible on several grounds, but primarily because of the tax-oriented nature of the Bulletin F assumptions, the long-run increasing physical durability of capital equipment, and the continued existence of voluminous business in used capital equipment.

It seems also reasonable to assume that whatever their exact lengths the actual service lives of capital assets in the United States have been shorter than in the U.S.S.R. This seems sensible not only on the grounds that a country poorer in capital would tend to use it longer than a rich country, but also on the grounds that the U.S.S.R. apparently places much greater emphasis on capital equipment repair than does the United States.[54] Soviet depreciation rates also strongly suggest a longer capital service life in that country than in the United States. Concerning the latter, it is interesting to note that according to P. Bunich, an apparently important participant in the 1959–62 reevaluation of Soviet capital stock, the average lifespan of fixed industrial capital, implicit in Soviet depreciation rates, was 27.5 percent longer than in the United States.[55] This comparison, reported in 1957, obviously made reference to the U.S. capital service lives assumed in the then official Bulletin F.

In order to determine to some extent the adequacy of the GNP and gross fixed business capital stock data used, I made a partial test of their consistency. The essence and the findings of this test are as follows:

(1) Converting the Soviet 1962 ruble value of gross fixed business capital stock into 1954 dollars (by means of Bornstein's cross-weighted purchasing power equivalent for investment goods) and dividing the total by the number of civilian employees, I find that in 1962 the dollar value of gross fixed business capital stock per civilian person employed in the Soviet economy constituted 37 percent of the U.S. figure when the U.S. estimate of the capital stock used assumes Bulletin F service lives, and 32 percent of the United States when the U.S. estimate assumes average service lives 20 percent longer than assumed in Bulletin F.[56]

(2) With respect to these ratios, I postulate that if the underlying estimates are mutually consistent they should not differ much from analogous ratios derived from the consumption of electric energy for productive purposes and from the consumption of mineral fuels in the two economies because these constitute the principal inputs used for the operation of business capital equipment. The calculations yield the following results:

In 1962 Soviet consumption of electric energy for productive purposes per person employed constituted about 36 percent of the U.S.

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[54] The Soviet publications devoted to the problem of capital equipment repair appear to be as numerous as those on planning, but far more impressive. Cf., e.g., Edinaia sistema planovo—predupreditelnogo remonta i ratsionalnoi ekspluatatsii technologicheskogo oborudovaniia mashinostroitelnykh predpriiatii (Standard System of Planned Preventive Repair of Industrial Equipment of Machine-Building Enterprises), 5th edition, Mashgiz, Moscow, 1964.

[55] P. Bunich, Amortizatsiia osnovnykh fondov v promyshlennosti (Depreciation of Capital Assets in Industry), Gostinisdat, Moscow, 1957, pp. 115–117, cited by Adam Kaufman, op. cit., p. IID–42. In an article which became available to me shortly before this study went to print Bunich states that the actual service lives of Soviet capital assets even considerably exceed the normatives (that is, those implied in depreciation rates). For reference to this article see note [138] below.

[56] See table 7 below for the ratios in the other years.

figure, and the consumption of mineral fuels (B.t.u.) per person employed was about 35 percent of the United States. From this I conclude that the Soviet estimate of gross fixed business capital stock is basically consistent with the estimate of the United States.

(3) Converting the Soviet 1962 ruble value of GNP into 1954 dollars (again by means of Bornstein's cross-weighted purchasing power equivalent for GNP) and dividing the total by the number of civilian persons employed, I reach the conclusion that in 1962 the dollar value of Soviet GNP per civilian person employed constituted about 32 percent of U.S.[57]

(4) With respect to this finding, I posed the following question: Is it plausible that the Soviet employed person equipped with some 35 percent as much productive capital as the U.S. employed person would produce about one-third the value of goods and services produced by the U.S. person? For answer to this question I looked into the history of productivity in the United States and inquired as to the analogous current records in other ("third") countries.

Researching U.S. history I find that in 1890, the most recent date, the value of gross fixed business capital stock per person employed in the economy was about 36 percent of that in 1962, and the value of the GNP per person employed in that year was about 30 percent of that in 1962.[58]

In regard to the record of "third" countries Edward F. Denison tells me that his nearly completed study shows that in 1960 gross fixed business capital stock per person employed in Italy was about 35 percent of the U.S. figure and the value of GNP per person employed 30 percent of the U.S. The correlation between the use of fixed business capital and output per person employed relative to the United States in other European countries is not as high as in Italy, but there are good reasons for that.

In the light of these findings I consider the data which I use as essentially meaningful and warrant the type of analysis I undertook.

COMPARISON OF FACTOR PRODUCTIVITY: THE ANALYSIS

The numerical analysis of the data described in the two preceding sections is set forth in tables 4, 5, 6, 6A, and 7.

Table 4 lists the indexes of GNP and six major inputs for the two countries in selected years between 1940 and 1962 (upper part) and the indexes of GNP per unit of the selected major inputs (lower part). Unlike the indicators of technological change presented in table 1, the data in table 4 cover the same time span for both countries and the subperiods are fully concurrent. The other difference between the data presented in table 1 and those presented in table 4 is that the latter omits 1958 because in both the U.S.S.R. and the United States that year is not suitable for productivity analysis.

Table 5, in turn, presents the rates of growth implicit in the indexes listed in table 4.

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[57] Ibid.

[58] Cf. John W. Kendrick, Productivity Trends in the United States, op. cit., table A–XVI, pp. 323–325 (U.S. capital stock in 1929 dollars); table A–IIa, pp. 293–297 (GNP estimates in 1929 dollars); table A–VI, pp. 305–307 (persons engaged) and Survey of Current Business, August 1965 (OBE deflators for GNP and gross private investment).

TABLE 4.—*Selected indexes bearing on changes in factor productivity in Soviet and U.S. economies, selected years, 1940–62*

[1940=100]

Type of index	U.S.S.R.				U.S.			
	1940	1950	1955	1962	1940	1950	1955	1962
I. Indexes of output (GNP) and selected major inputs:								
(0) GNP	100	124	172	257	100 [1] 100	156 [1] 141	193 [1] 172	233 [1] 211
(1) Civilian employment, unadjusted for changes in quality, sex composition, or hours worked	100	101	111	126	100 [1] 100	126 [1] 114	133 [1] 119	143 [1] 129
(2) Fixed business capital stock (gross of depreciation)	100	127	239	419	[2] 100	[2] 116	[2] 140	[2] 169
(3) Aggregated prime input:								
70/30 weights	100	108	141	184	100 [1] 100	123 [1] 115	135 [1] 126	149 [1] 140
70/25 weights	100	107	135	172	100 [1] 100	124 [1] 115	136 [1] 126	149 [1] 140
(4) Consumption of mineral fuels and fuel wood (BTU)	100	134	200	295	100	143	167	200
(5) Consumption of basic metals (steel ingot equivalent tonnage)	100	[3]	230	396	100	170	212	215
(6) Freight transportation (ton-miles)	100	146	239	434	100	172	206	225
(7) Fixed business capital/labor ratios	100	126	215	332	100 [1] 100	92 [1] 102	105 [1] 118	118 [1] 131
II. Indexes of GNP per unit of the selected major inputs:								
(1) GNP per man-year	100	123	154	204	100 [1] 100	123 [1] 123	145 [1] 145	164 [1] 164
(2) GNP per unit of fixed business capital stock (gross)	100	98	72	61	100 [1] 100	135 [1] 122	137 [1] 123	137 [1] 125
(3) GNP per unit of aggregated prime input:								
70/30 weights	100	115	123	141	100 [1] 100	127 [1] 122	143 [1] 136	155 [1] 151
75/25 weights	100	116	127	148	100 [1] 100	127 [1] 123	139 [1] 138	156 [1] 155
(4) GNP per unit (B.t.u.) of mineral fuels and fuel wood	100	93	86	87	100	108	115	116
(5) GNP per ton of basic metal input	100	[3]	75	65	100	92	91	109
(6) GNP per ton-mile of freight transportation	100	85	72	59	100	91	93	103

[1] Denotes, respectively, potential GNP, potential employment and other indexes calculated with respect to potential GNP.

[2] Based on estimate that assumes Bulletin F service lives of U.S. capital assets.
The procedure used in calculating the index of aggregated input and other estimates based on it is explained in note (b) to table 5.

[3] Not available.

Sources: Based on data set forth in app. C and the two sets of input weights. The 70/30 weights correspond to approximate labor (70 percent) and other resources (30 percent) income shares in the Soviet national income in 1959 as estimated by Stanley H. Cohn (for an as yet unpublished study, used here with the kind permission of the author.) It is assumed that these shares have been more or less stable over the period. They appear as one of three alternative calculations made by Bergson for 1937 and used for similar purposes to ours. Cf. A. Bergson and S. Kuznets, ed., Economic Trends in the Soviet Union, Harvard University Press, 1963, p. 19.

The 75/25 weights roughly correspond to the analogous average income shares in the United States in 1929–1962 as calculated by Edward F. Denison. This average was derived from The Sources of Economic Growth in the United States, Supplementary Paper No. 13, Committee for Economic Development, January 1962, p. 30 and the unpublished calculations for 1959–62 generously supplied to me by the author.

TABLE 5.—*Average annual growth rates bearing on changes in factor productivity in Soviet and U.S. economies, selected periods, 1940–62*

[Percent, rounded to one decimal]

Item	U.S.S.R.					U.S.				
	1940–62	1940–50	1950–62	1950–55	1955–62	1940–62	1940–50	1950–62	1950–55	1955–62
1. Growth rates of GNP and major inputs:										
(0) GNP	4.4	2.2	6.3	6.7	5.9	3.9 [1] 3.5	4.6 [1] 3.5	3.4 [1] 3.4	4.4 [1] 4.1	2.7 [1] 3.0
(1) Civilian employment (man-years)	1.1	.1	1.9	1.9	1.8	1.6 [1] 1.2	2.4 [1] 1.4	1.1 [1] 1.1	1.1 [1] 1.1	1.0 [1] 1.2
(2) Fixed business capital stock (gross)	6.7	2.4	10.5	13.5	8.4	2.4	1.5	3.2	3.8	2.7
(3) Aggregated prime inputs: [2]										
(a) 70/30 weights	2.8	.8	4.5	5.4	3.8	1.8 [1] 1.6	2.1 [1] 1.4	1.7 [1] 1.7	1.9 [1] 1.9	1.5 [1] 1.7
(b) 75/25 weights	2.5	.7	4.1	4.8	3.5	1.8 [1] 1.5	2.2 [1] 1.4	1.6 [1] 1.6	1.8 [1] 1.8	1.4 [1] 1.6
(4) Consumption of mineral fuels and fuel wood (B.t.u.)	5.0	3.0	6.8	8.4	5.7	3.2	3.6	2.9	3.1	2.6
(5) Consumption of basic metals (steel ingot equivalent tons)	6.5	[4]	[4]	[4]	8.1	3.5	5.4	2.0	4.5	.2
(6) Freight transportation (ton-mile)	6.9	3.9	9.5	10.4	9.0	3.8	5.6	2.3	3.7	1.3
(7) Fixed business capital/labor ratios	5.6	2.3	8.4	11.2	6.4	.8 [1] 1.2	[3] −.8 [1] .2	2.1 [1] 2.1	2.7 [1] 3.0	1.7 [1] 1.5
2. Growth of output (GNP) per unit of input:										
(1) GNP per unit of labor input (man-year)	3.3	2.1	4.3	4.7	4.0	2.3 [1] 2.3	2.1 [1] 2.1	2.4 [1] 2.4	3.3 [1] 3.3	1.7 [1] 1.7
(2) GNP per unit of fixed business capital stock	−2.2	−.2	−3.8	−6.0	−2.3	1.5 [1] 1.1	3.1 [1] 2.0	.2 [1] .2	.6 [1] .3	0.0 [1] .3
(3) GNP per unit of aggregated prime inputs:										
(a) 70/30 weights	1.6	1.4	1.7	1.3	2.0	2.0 [1] 1.9	2.4 [1] 2.0	1.7 [1] 1.6	2.4 [1] 2.2	1.2 [1] 1.3
(b) 75/25 weights	1.8	1.5	2.1	1.8	2.3	2.0 [1] 2.0	2.4 [1] 2.1	1.8 [1] 1.8	2.6 [1] 2.5	1.3 [1] 1.4
(4) GNP per unit of mineral fuels and fuel wood input (B.t.u.)	[3] −.6	−.8	−.5	−1.6	.2	.7	1.0	.5	1.3	.1
(5) GNP per ton of basic metals input	−2.0	[4]	[4]	[4]	−2.0	.4	−.8	1.4	−.1	2.5
(6) GNP per ton-mile of freight transportation	−2.3	−1.6	−2.9	−3.4	−2.8	.1	−.9	1.1	.7	1.4

[1] Denotes calculations with respect to potential GNP and inputs.

[2] The average rates of growth of aggregated prime inputs presented in the table represent weighted averages of the corresponding average rates of growth of labor and capital inputs. The algebraic formula used in the calculations is as follows:

$rnai = wlLn^{1-u} + wkKn^{1-u}$, where
$rnai$=geometric average rate of growth of aggregated labor and capital inputs for a period of n years,
wl and wk=respectively, labor and capital weights (income shares),
Ln=index of labor input (in ratio form) for the period, and
Kn=index of fixed business capital input (in ratio form) for the period.

The formula usually used for such calculations is: $rnai = (wlLn + wkKn)^{1-u}$ (implicit in John W. Kendrick, "Productivity Trends in the United States," Princeton University Press, Princeton, 1961, pp. 284–289 and tables D–III and D–IV, pp. 467–475).

The former formula was chosen in preference to the latter because of difficulties in economic interpretation of the "interaction effect" (in Denison's terminology) the latter formula has the tendency to produce when the indexes being aggregated are greatly dissimilar with respect to growth and/or more are extended over increasingly longer periods of time.

As for the United States the difference resulting from use of this or that formula is negligible but for the U.S.S.R. it is substantial. Using the latter (more conventional) formula to the Soviet indexes, our propositions with respect to the average annual rates of growth of aggregated inputs and output (GNP) per unit of aggregated inputs would have been as follows:

	1940–62	1940–50	1950–62
Average annual rate of growth of aggregated inputs:			
70/30 weights	3.5	0.9	5.4
75/25 weights	3.2	.7	4.9
Average annual rate of growth of output (GNP) per unit of aggregated inputs:			
70/30 weights	.9	1.3	.8
75/25 weights	1.2	1.5	1.3

Compared to the rates presented in the table, these rates imply substantially faster growth of the inputs and, inversely, lower growth of output per unit of input in all periods except 1940–50. Moreover, the difference is the greater the greater is the disparity between the growth rates implicit in the indexes of labor input, on one hand, and capital input, on another, and the longer the period of time covered by these indexes. This is obviously the effect of mathematical properties of the formula rather than a proper reflection of the genuine economic phenomena being analyzed.

From the point of view of substantive analysis, therefore, the estimates presented in the table are believed to be better measures of what they purport to represent than those that would have been presented had the more conventional formula been used. All other measures presented in this study that involve the data on aggregated prime inputs have been prepared in accordance with the stated procedure.

(For discussion of the problem of "interaction," see Edward F. Denison, "The Sources of Economic Growth in the United States," op. cit., n. 15, pp. 104–105, and note 7, p. 153 and Herbert S. Levine, "A Small Problem in Analysis of Growth," The Review of Economics and Statistics, May 1960.)

[3] Minus sign (−) denotes decline.

[4] Not available.

Source: Table 4.

The analysis of aggregate (total) factor productivity set forth in tables 4 and 5 essentially follows Kendrick's pattern; that is, it focuses on the average annual growth of GNP per unit of aggregated factor input. The results are compared with the Solow-type estimate of technical change.

Tables 6 and 6A amplify the analysis presented in tables 4 and 5 by focusing on the aggregate factor productivity as a source of GNP growth in the two economies in the manner similar to Denison's approach. The tabulations in table 6 serve also as a reference for the analysis of the relationships between the aggregate factor productivity in the two economies and the respective countries' growth of fixed business capital stock.

Table 7, finally, presents the basic data underlying the indexes listed in table 4 for the U.S.S.R. as a percent of U.S. figures. The objective of this third alternative presentation of the data is to show the implications of the differential changes in factor productivity for each country's position relative to the other in a more assessable form.

Bearing in mind what has been said in the preceding section concerning the limitations as well as the basic consistency of the data used, the analytical implications of the calculations presented in these tables should be, by and large, self-explanatory. In the text that follows I shall therefore focus only on those features of the data that lead to the most important conclusions or to which references are made in later parts of the study.

Comparative growth of GNP and the inputs

The comparative growth of GNP in the two countries is shown in the upper portions of tables 4 and 5. It will be noted that the U.S.S.R.'s growth makedly exceeded that of the United States in all nonwar periods irrespective of whether we use actual or potential GNP as a measure of U.S. performance. Moreover, the excess of Soviet GNP growth over the United States has tended to be greater in relation to potential U.S. growth than in relation to the actual. The excess of Soviet GNP growth over the U.S. actual growth was about 13 percent in the 1940–62 period as a whole, about 85 percent between 1950 and 1962, about 50 percent between 1950 and 1955, and about 120 percent between 1955 and 1962. Relative to the U.S. potential GNP, however, the Soviet growth between 1940 and 1962 was higher by 25 percent, between 1950 and 1962 by 85 percent (same as compared with the actual GNP), between 1950 and 1955 by 67 percent, and between 1955 and 1962 by 97 percent. There is no point, of course, to argue about the lower growth in GNP in the Soviet Union than in the United States between 1940 and 1950.

Although these comparisons contain little discovery on my part, I am noting them because, first of all, the type of analysis which I pursue makes mention of them mandatory and, second, the mere fact of faster growth in the U.S.S.R. than in the United States has been widely used (not only by the U.S.S.R., but also by some Western scholars) as a proof of greater efficiency capabilities of the Soviet economic system. This, of course, is one of the questions at issue in this study.

Turning to the comparison of growth of labor inputs in the two economies we should note an almost complete absence of the growth of this input in the U.S.S.R. between 1940 and 1950, due to the calamities of World War II; a rapid growth between 1950 and 1955; and a slowdown of growth in the 1955–62 period, which must be interpreted as an echo of World War II (being the result of drastically declined birth rates during the war). As for the United States, the notable points are a considerably faster growth of actual than potential employment, technically caused by a higher unemployment rate in 1940 than in any subsequent years; and the apparent decline in actual and increase in potential employment between 1955 and 1962. Comparatively, the average Soviet growth in civilian employment has been very similar to the growth of U.S. potential employment for the 22-year period as a whole, but between 1950 and 1962 the Soviet growth was considerably faster than either of the U.S. rates.

The rate of growth in Soviet fixed business capital input has also exceeded the U.S. growth, even during the 1940–50 period. In fact, this excess has been much larger than either in GNP or labor input: between 1940 and 1962 the excess averaged about 180 percent; between 1940 and 1950, 60 percent; between 1950 and 1962, 228 percent; between 1950 and 1955, 255 percent; and between 1955 and 1962, 211 percent.

The enormously faster rate of Soviet fixed business capital formation than that of the United States is in sharp contrast to the lag in relative rate of technological progress. This contrast obviously implies that the bulk of the fixed business capital added annually to the stock of the Soviet economy must have been in the form of a simple enlargement of what had been used before or, what amounts to the same thing, that a dollar's worth of the capital added to the stock of the Soviet economy had contained substantially fewer progressive elements (in fact, only some 20 to 25 percent) than a dollar's worth of the capital added to the stock of the U.S. economy.

The growth of aggregated prime inputs represent simply weighted averages of the growths of labor and capital inputs. Since both labor and capital inputs grew faster in the U.S.S.R. than in the United States, the Soviet growth of aggregated input was faster as well. It will be noted in tables 4 and 5, however, that irrespective of the economy, the use of 70–30 (Soviet) weights results in a faster growth of the input than the use of U.S. (75–25) weights, but the divergence is greater in the U.S.S.R. indexes than in the United States. This is caused by greater disparity in the growths of the labor and capital indexes of the U.S.S.R. than in those of the United States. The ratio of overall growth of capital input to that of labor input is 6.7 to 1.1 in the U.S.S.R., but only 2.4 to 1.2 (potential) in the United States. Therefore, the smaller the weight assigned to the capital input in the U.S.S.R., the lower will be the aggregate input index both relative to its own GNP and relative to the United States. This tendency causes the comparative aggregated factor productivity indexes calculated on the basis of the factor input indexes using U.S. weights to be somewhat biased in favor of the Soviet economy.

Another point that might be noted regarding the indexes of aggregated inputs is that there is a small asymmetry between the U.S. indexes of actual and potential inputs. The reason for this is that in calculating the index of actual inputs no adjustments were made in the index of capital input for changes in the degree of capital utilization over time.

The comparative growths in GNP and the labor, capital, and aggregated inputs are all that are needed for formal comparative factor productivity analysis. For purposes of estimating Solow's type of technical change (for comparison with estimates of aggregate factor productivity) we need also the growths in the capital to labor ratios. These are listed as items 7 in the upper portion of tables 4 and 5. Since the Soviet growth in fixed business capital stock relative to the United States was much faster than that in labor input, the growth in the Soviet capital to labor ratio must have been much faster than in the United States as well.

The role of the other data for the analysis listed in the tables; namely, consumption of mineral fuels and wood fuel, consumption of basic metals, and input of freight transportation is auxiliary and their contribution to the analysis will be fully apparent only in the discussion of part VI. Here it suffices only to recollect that in the U.S.S.R. these inputs represent areas of low rate of technological change and to note (table 5) that their growth more or less paralleled the growth of (economywide) fixed business capital stock and substantially exceeded the growth of GNP. In the United States, however, these inputs represent the areas of marked technological progress (between 1940 and 1962, of course), and their growth grossly exceeded that of (economywide) gross fixed business capital stock, but lagged behind the growth of GNP.

Comparative growth in output (GNP) per unit of labor and per unit of capital inputs

The Soviet output (GNP) per man-year increased about 104 percent or an average of 3.3 percent per year in the 1940–62 period as a whole; about 66 percent, or 4.3 percent per year, between 1950 and 1962; 25 percent, or an average of about 4.7 percent per year, between 1950 and 1955; and 32 percent, or an average 4 percent per year, between 1955 and 1962.

Although this Soviet growth in labor productivity cannot be termed spectacular, particularly in comparison with such countries as Japan, Germany, France, and Italy,[59] it is certainly impressive in comparison with the United States. In the 22 years between 1940 and 1962, the U.S. output (GNP) per man-year increased only about 64 percent, or 2.3 percent per year, which is almost 40-percent less than in the U.S.S.R. All of the excess in the Soviet productivity of labor over the United States accrued in the 1950–62 period, and the excess was largest, 135 percent, between 1955 and 1962.

[59] Cf. previously cited studies by Stanley H. Cohn, pages, respectively, 9 and 15; Angus Maddison, "Soviet Economic Performance," Banca Nazionale del Lavoro, Quarterly Review, March 1965, p. 13, and table 8 below.

The trend in output per unit of fixed business capital input in the Soviet economy, however, is for all practical purposes the reverse of both the economy's own trend in productivity of labor and the trend of capital productivity in the United States. As shown in section II of tables 4 and 5, the Soviet index of GNP per unit of capital for the 1940–62 period indicates an overall decline in capital productivity of some 39 percent or about 2.2 percent per year. Between 1940 and 1950 this decline was very small, only about two-tenths of 1 percent per year, but between 1950 and 1955 it averaged 6 percent per year and between 1955 and 1962 some 2.3 percent per year.

In the United States the changes in the index of GNP per unit of fixed business capital depend to a large extent on whether the index is calculated with reference to actual or potential GNP, but in either case the data point out to a rather substantial increase in productivity of capital. In terms of actual GNP the overall increase in U.S. productivity of capital over the 22-year period was 37 percentage points, almost as large as the Soviet decline, and in terms of potential GNP the U.S. increase was 25 percent or almost two-thirds as large as the Soviet decline. In each case, however, most of the increase in the U.S. productivity of capital accrued between 1940 and 1955. Since 1955 there seems to have been a continuation of an upward capital productivity trend with reference to potential GNP, but not with reference to the actual.

Comparative growth in output (GNP) per unit of aggregated input

The weighted sums of the respective indexes of labor and capital productivity, with proper consideration obviously given to the rebasing of the underlying indexes at each change of the reference year, are equivalent to the indexes of aggregate factor productivity.

As shown in section II of tables 4 and 5, the Soviet index of output (GNP) per unit of aggregated inputs based on 70/30 input weights indicates an increase by 41 percent over the 22-year period, which is equivalent to an average growth of roughly 1.6 percent per year. The index based on 75/25 weights, however, shows an increase of 48 percent in the same time span, equivalent to average growth of 1.8 percent per year. The judgment with respect to aggregate factor productivity growth in the Soviet economy thus depends to a large extent on the input weights, especially the weight assigned to capital input. A decrease in the capital weight by 5 percentage points (from 30 to 25) results in a 17-percent higher increase in aggregate factor productivity, from 41 to 48. The obvious reason for this is the declining productivity of capital: the more importance we assign to it, the lower is the growth of the economy's overall productivity. In terms of either measure, the period of fastest Soviet growth in output per unit of aggregated input, 2.0 to 2.3 percent per year, was between 1955 and 1962. The period between 1940 and 1950, with an average annual growth in output per unit of aggregated input of 1.4 to 1.5 percent per year, ranks second, but very close to the average for the 22 years. The probability is, however, that the bulk of the productivity increase in that period was achieved between 1945 and 1950, the time of the economy's reconstruction, and if that is the case the rate of growth

in aggregate factor productivity in the reconstruction period alone must have been about twice as large as estimated for the 1940–50 period, and about 50 percent higher than the rate achieved between 1955 and 1962. As is evident from other data in the tables, the 1940–50 period was marked by a small growth in GNP (althought it must have been higher between 1945 and 1950), a slight growth in labor input, and only a moderate growth in the fixed business capital input.

The index of output (GNP) per unit of aggregated inputs of the United States increased in the 22-year period by 55 to 56 percent, or, on the average, about 2 percent per year, when calculated with respect to actual GNP; and 51 to 55 percent, or 1.9 to 2 percent per year, when calculated in terms of potential GNP. The obvious reason for the higher growth in U.S. aggregate factor productivity in terms of actual rather than potential GNP is that the unemployment rate and, hence, the difference between the actual and potential GNP was substantially larger in 1940 than in 1962, and the combination of relatively higher potential GNP in the base year (1940) and lower in terminal year (1962) resulted in a smaller potential growth rate. In the 22-year period as a whole, the growth of output per unit of aggregated input in the United States was thus some 18 percent higher than the Soviet rate when the U.S. rates are calculated with reference to actual GNP, and about 15 percent higher when calculated with reference to potential GNP.

All of the U.S. lead in aggregate factor productivity over the U.S.S.R. for the 22-year period accrued, however, by 1955. In the 1955–62 period the U.S. growth of 1.2 to 1.4 percent per year constituted only 60 percent of that in the U.S.S.R. at the time.

Parenthetically I should point out, however, that the 1955–62 estimates are not representative for "longrun" performance of either the U.S.S.R. or the United States. The apparent acceleration in the Soviet total productivity growth in that period was largely the result of an exceptionally good performance between 1955 and 1958 when the Soviet total factor productivity grew almost 4 percent per year, and poor performance between 1958 and 1962 when this productivity grew at the rate of only about 1 percent per year. If the analysis were extended through 1965, the Soviet performance for the 1955–65 period would probably be about the same as in 1950–62 or worse because in 1962–65, as shall be pointed out in Part VII, this productivity grew at the rate of only about $\frac{7}{10}$ of one percent. The considerable decrease in the U.S. total factor productivity growth in the 1955–62 period, in turn, was the result of a zero growth between 1955 and 1958, and a growth by about 2.3 percent per year between 1958 and 1962. If the analysis were extended through 1965, the U.S. total productivity for the decade between 1955 and 1965 would show a slower growth than in the decade preceding 1955, but about the same as the average between 1950 and 1962.

The possibilities of analyzing the data in terms of "production function" approach

The readers who would prefer to pursue the foregoing analysis in terms of the production function rather than the aggregate factor productivity approach in a full scope can obviously do so by making only a few additional calculations from the data shown in tables 4 and 5. For those who might be interested in a mere comparison of the overall propositions to result from the application of the two approaches, the following calculations based on the formula (1) discussed in part I and the 70/30 input weights (b=0.30) should suffice:

	1940–62	1940–50	1950–62
U.S.S.R.:			
$\frac{\Delta(Q/L)}{Q/L}$ equals (Percentage change in output per head.)	3.3	2.1	4.3
$-b\frac{\Delta(K/L)}{K/L}$ equals (Contribution of substitution of capital for labor.)	−1.7	−.7	−2.5
$\Delta A/A$ equals ("Technical change.")	1.6	1.4	1.8
United States (potential):			
$\frac{\Delta(Q/L)}{Q/L}$ equals (Percentage change in output per head.)	2.3	2.1	2.4
$-b\frac{\Delta(K/L)}{K/L}$ equals (Contribution of substitution of capital for labor.)	−.36	−.06	−.6
$\Delta A/A$ equals ("Technical change.")	1.94	2.04	1.8

Thus, compared with the figures for total factor productivity described in the preceding section (and shown in table 5, sec. II), the estimates of "technical change" are for all practical purposes identical. The differences, in no case exceeding one-tenth of 1 percentage point, are apparently due to roundings. In the context of our analysis, however, consideration of substitution of capital for labor in addition to technological progress and capital productivity has proven valuable for proper interpretation of the findings [60] set forth in part V.

Growth of aggregate factor productivity as a source of growth in GNP

Turning to the growths in output per unit of aggregate factor input as a source of overall growth in the two economies as shown in tables 6 and 6A, two points stand out.

[60] I am indebted to James W. Knowles for helpful comment on this point.

TABLE 6.—*Comparison of sources of GNP growth in Soviet and United States economies, selected periods, 1940–62*

[In percentage points]

Country and source of growth	1940–62			1940–50			1950–62			1950–55			1955–62		
	Average annual growth of specific input and GNP	Average annual contribution of inputs and productivity to growth of GNP		Average annual growth of specific input and GNP	Average annual contribution of inputs and productivity to growth of GNP		Average annual growth of specific input and GNP	Average annual contribution of inputs and productivity to growth of GNP		Average annual growth of specific input and GNP	Average annual contribution of inputs and productivity to growth of GNP		Average annual growth of specific input and GNP	Average annual contribution of inputs and productivity to growth of GNP	
		70–30 input weights	75–25 input weights		70–30 input weights	75–25 input weights		70–30 input weights	75–25 input weights		70–30 input weights	75–25 input weights		70–30 input weights	75–25 input weights
U.S.S.R.:															
Labor input (man-years)	1.10	0.77	0.82	0.10	0.07	0.08	1.9	1.33	1.43	1.90	1.33	1.43	1.80	1.26	1.35
Fixed business capital stock	6.70	2.01	1.68	2.40	.72	.60	10.5	3.15	2.63	13.50	4.05	3.38	8.40	2.52	2.10
Aggregated prime inputs	----------	2.78	2.51	----------	.79	.68	----------	4.48	4.06	----------	5.38	4.81	----------	3.78	3.45
Residual (productivity)	----------	1.62	1.89	----------	1.41	1.52	----------	1.82	2.24	----------	1.32	1.89	----------	2.12	2.45
Total (GNP)	4.40	4.40	4.40	2.20	2.20	2.20	6.3	6.30	6.30	6.70	6.70	6.70	5.90	5.90	5.90

United States (actual):															
Labor input (man-years)	1.60	1.12	1.20	2.40	1.68	1.80	1.1	.77	.83	1.10	.77	.83	1.00	.70	.75
Fixed business capital stock	2.40	.72	.60	1.50	.45	.38	3.2	.96	.80	3.80	1.14	.95	2.70	.81	.68
Aggregated prime inputs		1.84	1.80		2.13	2.18		1.73	1.63		1.91	1.78		1.51	1.43
Residual (productivity)		2.06	2.10		2.47	2.42		1.67	1.77		2.49	2.62		1.19	1.27
Total (GNP)	3.90	3.90	3.90	4.60	4.60	4.60	3.4	3.40	3.40	4.40	4.40	4.40	2.70	2.70	2.70
United States (potential):															
Labor input (man-years)	1.20	.84	.90	1.40	.98	1.05	1.1	.77	.83	1.10	.77	.83	1.20	.84	.90
Fixed business capital stock	2.40	.72	.60	1.50	.45	.38	3.2	.96	.80	3.80	1.14	.95	2.70	.81	.68
Aggregated primie inputs		1.56	1.50		1.43	1.43		1.73	1.63		1.91	1.78		1.65	1.58
Residual (productivity)		1.94	2.00		2.07	2.07		1.67	1.77		2.19	2.32		1.35	1.42
Total (GNP)	3.50	3.50	3.50	3.50	3.50	3.50	3.4	3.40	3.40	4.10	4.10	4.10	3.00	3.00	3.00

NOTE.—In form, this tabulation of the data follows the model used in Edward F. Denison's pioneering work referred to earlier. In substance, however, it differs from Denison's in that Denison assumes that such qualitative factors as education, changes in age-sex composition of the labor force, economies of scale, etc., contribute to the growth of GNP directly whereas this model assumes that these factors contribute to the overall growth through technology (advanced knowledge put to use largely through improvements of capital goods) or organization.

It would be exceedingly interesting to analyze the Soviet economic growth in the detail that Denison did for the United States. I was tempted to do this but found it impossible with the time and resources at my disposal. Very rough calculations indicate, however, that in such a detailed study the contributions of physical inputs and all the qualitative factors calculated the way Denison did for the United States would "overexhaust" the total growth, and the contribution of "advanced knowledge" (Denison's "residual") would be negative. This would be tantamount to a conclusion that there had been a technological regress. In the face of independent evidence to the effect that there had been a positive technological progress, this would present an analytical dilemma. This dilemma could be resolved, however, by redefining the "advanced knowledge" residual into technology proper and institutional organization, assigning a positive contribution to technology proper in accordance with the independently available information on the extent of technological progress actually introduced into the economy (a difficult job but by no means impossible), and assigning the negative contribution (which would be even larger than the initial one) to the new residual of institutional organization or economic system. Thus defined, negative contribution of the system would be a measure of the system's inefficiency, but only a partial measure. A full estimate of the system's inefficiency would also have to take into account the extent to which it was failing to make use of objective opportunities for faster technological progress of the economy than it actually did.

As shall become apparent in the text, I am trying to tangle with some of these problems, but in much more aggregative terms.

Sources: Calculated from table 5. The contribution of each input to growth of GNP is assumed to equal to the percentage growth of the input multiplied by its share in national income. See note (b) to table 5.

The first is that, contrary to the previously mentioned widely held view about "growth equals efficiency," in both economies there is an almost complete lack of correlation between the overall economic (GNP) growth and the growth in aggregate (total) factor productivity. Despite the high overall growth of the Soviet economy, the only period in which that economy derived more than 50 percent of its total growth from growth of productivity is between 1940 and 1950, the period of its lowest GNP growth. And in the United States, for example, the growth of actual GNP between 1940 and 1950 was considerably higher than between 1950 and 1962, but the percentage of growth that the economy derived from the productivity was about the same in both periods.

TABLE 6A.—*Proportional relationship of sources of economic growth (GNP) in Soviet and U.S. economies, selected periods, 1940–62*

(Percent)

Country and source of growth	1940–62		1940–50		1950–62		1950–55		1955–62	
	70/30 input weights	75/25 input weights	70/30 input weights	75/25 input weights	70/30 input weights	75/25 input weights	70/30 input weights	75/25 input weights	70/30 input weights	75/25 input weights
U.S.S.R.:										
Labor input	17	19	3	4	21	22	20	22	21	23
Fixed business capital stock	46	38	33	27	50	42	60	50	42	36
Aggregated prime inputs	63	57	36	31	71	64	80	72	63	59
Residual (productivity)	37	43	64	69	29	36	20	28	37	41
Total (GNP)	100	100	100	100	100	100	100	100	100	100
United States (actual):										
Labor input	29	31	30	39	23	24	17	18	26	28
Fixed business capital stock	18	15	10	8	28	24	26	22	30	25
Aggregated prime inputs	47	46	46	47	51	48	43	40	56	53
Residual (productivity)	53	54	54	53	49	52	57	60	44	47
Total (GNP)	100	100	100	100	100	100	100	100	100	100
United States (potential):										
Labor input	24	26	28	30	23	24	19	20	28	30
Fixed business capital stock	21	17	13	11	28	24	28	23	27	23
Aggregated prime inputs	45	43	41	41	51	48	47	43	55	53
Residual (productivity)	55	57	59	59	49	52	53	57	45	47
Total (GNP)	100	100	100	100	100	100	100	100	100	100

Source: Table 6.

The second and more important point is that the Soviet economy derived a greater proportion of its overall growth from the growth of productivity than did the United States only between 1940 and 1950, the period of the lowest Soviet growth. In all other periods the proportion of the Soviet overall growth derived from productivity was considerably lower than in the United States: between 1950 and 1962 about two-thirds; between 1950 and 1955 about two-fifths; and between 1955 and 1962 about four-fifths.

The most important corollary to this conclusion is that the whole secret of higher overall growth of the Soviet economy than in the

United States in the 1940–62 period as a whole, as well as between 1950 and 1962, 1950 and 1955, and between 1955 and 1962, is fully explainable by higher growth of physical inputs. Moreover, as is apparent in table 6, in the 1940–62 and 1950–55 periods the disparity between the Soviet and the United States growth in fixed business capital stock alone was more than sufficient to produce the difference between the GNP growths that actually occurred. Indeed, these data indicate that in those periods capital investment was used in the Soviet economy not only to produce the net excess in the overall growth over the United States, but also to cover the lag in the growth of productivity. That this could be done in the conditions of as low standard of living as prevailed in the U.S.S.R. throughout the period [61] must obviously be attributed to the dictatorial power rather than to the economic virtues of the system.

Ratios of average annual percentage growth in aggregate factor productivity to the average annual percentage growth in fixed business capital stock

Disregarding the factors other than new technology that affect the rate of total factor productivity growth and assuming that new technology is always embodied in the capital newly added to the economy, these ratios might be assumed to represent the measures of the effects of embodied technical changes more or less in the sense postulated in the "embodiment" models. Without these restrictive assumptions we might simply interpret them as percentage growth in total factor productivity per percentage increase in fixed business capital stock.

In a broad sense, these ratios might obviously be also interpreted to measure the relative returns to the economies' additions of fixed business capital stock. Even more philosophically stated, assuming, as a first approximation, an unlimited potential availability of new technological and managerial know-how in both countries, these ratios might also be considered to represent relative measures of effective utilization of potentialities for productivity growth.

Implicit in table 6, these ratios for the two countries are as follows:

Period	U.S.S.R.		United States (actual)		United States (potential)	
	70/30 input weights	75/25 input weights	70/30 input weights	75/25 input weights	70/30 input weights	75/25 input weights
1940–62	0.24	0.28	0.86	0.88	0.81	0.83
1940–50	.59	.63	1.65	1.61	1.38	1.38
1950–62	.17	.21	.52	.55	.52	.55
1950–55	.10	.14	.65	.69	.58	.61
1955–62	.25	.29	.44	.47	.50	.53

Thus, as a first approximation, these ratios indicate that in the 1940–62 period as a whole the Soviet economy's effective utilization of potentialities for productivity growth averaged only 28 to 33 percent of the United States. In the post World War II period this Soviet "effort" still averaged only about 36 percent of that in the United States, but between 1955 and 1962, the most recent period, it advanced to as much as 55 to 57 percent of the United States.

[61] Cf. Janet Chapman, "Real Wages in Soviet Russia Since 1928," Harvard University Press, Cambridge, Mass., 1963.

Another point of note in regard to these ratios is that in the U.S.S.R. there is a complete lack of correlation between the growth in total factor productivity and growth in fixed business capital stock. In the United States there seems to be some correlation between these two variables, but it is marked only in the post World War II years.

Changes in the position of the Soviet economy relative to the United States

All of the comparative changes in factor productivity described in the preceding analysis imply substantial changes in the position of each country relative to the other. These changes are brought out in table 7. The comparisons in this table focus on changes in the percentage relationship of overall aggregates (sec. I), changes in the percentage relationships of input requirements per unit (dollar's worth) of GNP (sec. II), and percentage relationship of output (GNP) and gross fixed business capital stock per person employed (sec. III).

TABLE 7.—*Selected indicators of changes in the position of Soviet economy relative to the United States, selected years, 1940–62*

(U.S.S.R. as percent of United States)

Type of indicator	1940	1950	1955	1962
I. OVERALL AGGREGATES				
(o) Soviet GNP as percent of U.S. actual GNP (In comparable purchasing power equivalents)	42.2	33.3	37.6	46.6
(oa) Soviet GNP as percent of U.S. potential GNP	36.1	31.5	35.9	44.0
(1) Soviet civilian employment as percent of U.S. employment	166.2	132.7	138.4	146.5
(1a) Soviet civilian employment as percent of U.S. labor force (potential employment)	141.9	125.7	132.3	138.3
(2) The value of Soviet fixed business *gross* capital stock as percent of United States:				
(a) Assuming service lives of capital in United States as postulated in Bulletin F	21.6	23.6	37.0	53.8
(b) Assuming service lives in United States 20 percent longer than postulated in Bulletin F	18.3	19.8	32.0	46.4
(3) Input of mineral fuels and fuel wood (B.t.u.)	28.3	26.5	33.8	41.8
(4) Input of basic metals (steel ingot equivalent tonnage)	40.3	[1]	43.8	74.5
(5) Approximate input of freight transportation (ton-miles)	54.1	44.1	59.5	97.4
(6) Input of electric energy (kilowatt-hours)	29.7	23.0	26.7	38.8
II. SOVIET USE OF INPUTS PER UNIT (DOLLAR'S WORTH) OF GNP AS PERCENT OF U.S. (ACTUAL)				
(1) Labor (man-years)	394.8	398.5	368.1	314.4
(2) Fixed business capital:				
(a) Assuming Bulletin F lives	51.3	70.9	98.4	115.4
(b) Assuming lives 20 percent longer	43.4	59.4	85.1	99.6
(3) Mineral fuels and fuel wood (B.t.u.)	67.2	79.6	89.9	89.7
(4) Basic metals (steel ingot equivalent tonnage)	95.7	[1]	116.5	159.9
(5) Intercity freight transportation (ton-miles)	128.5	132.4	158.2	209.0
(6) Electric energy (kilowatt-hours)	70.5	69.1	71.0	83.3
III. OUTPUT AND CAPITAL PER CIVILIAN PERSON EMPLOYED				
(1) Soviet GNP per person employed as percent of U.S. (actual)	25.4	25.1	27.1	31.8
(2) Soviet fixed business capital stock per civilian person employed as percent of U.S. fixed business capital stock per person employed, assumed Bulletin F Service lives in United States	13.0	17.8	26.7	36.7
Same, assumed service lives 20% longer than Bulletin F in United States	11.0	14.9	23.1	31.7

[1] Not available.

Sources: Calculated from the data set forth in app. C. In derivation of the percentage relationships in GNP and business fixed capital in 1955 rubles were converted into the 1954 U.S. dollars by means of conversion ratios, respectively, 0.868 and 0.610 (post 1961) rubles per dollar. These ratios correspond to Bornstein's geometrically weighted 1955 ruble/dollar purchasing power equivalents constructed with United States and Soviet weights for GNP and gross investment, adjusted for respective price changes in the United States between 1954 and 1955. *Cf.*, Morris Bornstein, "A Comparison of Soviet and United States National Product," Comparisons of the United States and Soviet Economies, Joint Economic Committee, Congress of the United States, pt. II, Washington, 1959, table 3, p. 385, and Survey of Current Business, August 1965 (implicit deflators for U.S. GNP and gross investment).

Among the percentage relationships of overall aggregates the most important are, of course, the changes in the size of the Soviet GNP relative to the United States. As shown in the table, the Soviet GNP increased depending on whether the referennce is to the estimate of U.S. potential or acutal GNP, from 36.1 or 42.2 percent of the United States in 1940 and 31.5 or 33.3 in 1950 to 44.0 or 46.6 percent of the United States in 1962. The gain of, respectively, 7.9 or 4.4 percentage points between 1940 and 1962 is modest, but the 12.5 or 13.3 percentage points between 1950 and 1962 alone are undoubtedly impressive.

As a result of slower growth in labor input, however, the Soviet economy's total employment as percent of U.S. declined: from 166.2 in 1940 to 146.5 in 1962, a loss of 19.7 precentage points when the reference is to the U.S. actual employment; and from 141.9 to 138.3, or 3.6 percentage points when the reference is to the U.S. potential employment (labor force). Between 1950 and 1962 alone, however, the Soviet employment as a percent of U.S. increased by 13.8 percentage points irrespective of whether the refence is to the U.S. potential or actual employment (because of identical unemployment rates in both years in the United States).

In 1940 and 1950 the Soviet use of labor input per dollar's worth of GNP had been almost four times as large as in the United States, or, inversely, the output per head had been only about 25 percent of that in the United States. Between 1950 and 1962, because of faster growth in labor productivity in the U.S.S.R. than in the Unittd States, the Soviet labor input requirement declined to the level of slightly over three times that in the United States (output per head increased to the level slightly less than one-third of that in the United States).

It is also important to note that the relative decline in the Soviet input of labor per dollar's worth of GNP by some 20 percent over the 22-year period (from about 395 percent to 314 percent) was accompanied by a rise in the relative capital labor ratio, from only 11 or 13 percent in 1940 and about 15 to 18 percent in 1950, to about 32 or 37 percent in 1962, that is, there was an increase by some 190 percent between 1940 and 1962 and 110 percent between 1950 and 1962 alone.

The result of the Soviet growth in the fixed business capital stock almost three times as fast as the growth in the United States was of course, a large improvement in the Soviet economy's relative position in this respect. In 1940 the value of gross fixed business capital stock of the Soviet economy constituted only some 18.3 or 21.8 percent of that in the United States depending on whether we assume the Bulletin F or 20 percent longer service lives of capital assets in the United States, but by 1962 these percentages increased to, respectively 46.4 or 53.8. The total gain in the Soviet economy's position relative to the United States over the 22-year period in regard to the availability of gross fixed business capital thus was about 28.1 or 32.2 percentage points, or some four to more than seven times as large as the gain in GNP. Virtually all of this gain accrued between 1950 and 1962. In order to produce a dollar's worth of GNP, the Soviet economy used only about half as much fixed business capital as the United States used in 1940, but by 1950 this ratio increased to about 60 or 70 percent, and by 1962 to about 100 or 115 percent.

With respect to changes in the position of the Soviet economy relative to the United States in terms of the four other aggregate inputs,

the interesting things are not only the gains but also the heterogeneity of these gains: of each input in relation to another and in relation to the gains in GNP and fixed business capital stock.

The relative magnitude of the Soviet input of mineral fuels and wood fuel increased over the period 1940–62 by 13.5 percentage points, about three times as much as the gain in GNP (relative to the U.S. actual), but only 40 percent as much as the gain in the fixed business capital. In the 1950–62 period alone, however, the gain was 15.3 percentage points, only 2 percentage points larger than the gain in GNP and about half as large as in fixed business capital stock. For dollar's worth of GNP, the Soviet economy's use of this input had been at a level of about two-thirds that in the United States in 1940, by 1950 it increased to about four-fifths of the U.S. level, and by 1962 to about 90 percent of the U.S. level.

In terms of the relative magnitude of aggregate input of basic metals the Soviet economy gained 34.2 percentage points from 1940 to 1962, almost eight times as much as in GNP and some some 2 to 6 percentage points more than the gain in fixed business capital stock. Although the data for the metals input are not available for 1950 it seems reasonable to assume that virtually all of the 1940–62 gain actually accrued between 1950 and 1962. In that case, this gain in the metals input was more than twice the gain in GNP and somewhat larger than the gain in fixed business capital stock of that period. Per dollar's worth of GNP, the Soviet economy's input of basic metals had already been almost at the same level as in the United States in 1940. By 1962 it exceeded the U.S. level by almost 60 percent.

The relative magnitude of Soviet freight transportation increased about 43 percentage points over the 1940–62 period, almost 10 times as much as the gain in GNP and some 11 to 15 percentage points more than the gain in fixed business capital stock. In 1950–62 alone the gain in the freight transportation was 53.3 percentage points, four times as large as in GNP and about 80 percent larger than in fixed business capital stock. Related to dollar's worth of GNP the Soviet use of freight transportation had already been about 29 percent larger than the United States in 1940, and by 1962 this excess increased to more than 100 percent.

The Soviet growths in inputs of mineral fuels, basic metals and freight transportation relative to the GNP just described strongly suggest that they should have been important factors for the required growth of business capital stock in excess of growth of GNP and, hence, contributors to the decline of the capital productivity in the U.S.S.R. As shall become evident in the discussion of part VI, this was indeed the case.

Of the four specific inputs, the Soviet economy gained relatively least in the total input of electric energy. Over the 1940–62 period this gain was only 9.1 percentage points, about twice as much as in GNP, but only about one-third as much as in fixed business capital; and the gain in 1950–62, 15.8 percentage points, was only about 2.5 percentage points greater than the gain in GNP and not quite half as large as the gain in the fixed business capital stock. Per dollar's worth of GNP, the Soviet economy had used about 70 percent as much electric energy as the United States in 1940 and 1950, and by 1962 this relative level appears to have increased to about 83 percent.

This analysis has touched several times upon the question of efficiency of the Soviet economy relative to the United States. This problem is the main topic of the discussion in the two parts of the study that follow.

V. Major Implications of the Findings of the Comparisons of Technological Progress and Factor Productivity

The consistency of the overall findings and the key implications

It is possible to think of at least half a dozen reasons why the analysis of the comparative progress in technology set forth in part III and the analysis of the comparative aggregate factor productivity in part IV could have produced considerably different results. In fact, had I conducted the analysis in terms of shorter periods, or extended it through 1965, we would have had the opportunity to observe that at certain times the rate in total factor productivity growth can deviate considerably from the rate of technological progress. As for the periods under primary focus of this study we must conclude, however, that the results of the entirely independent comparative analysis of technological analysis on one hand, and the analysis of aggregate factor productivity, on the other, are for most practical purposes identical. Indeed, our finding of a substantially smaller rate of technological progress in the U.S.S.R. than in the United States in the 1939/40–1962 period as a whole is paralleled by the U.S.S.R.'s smaller rate of growth in total factor productivity. The finding of a virtual parity in the Soviet rate of technological progress with that in the United States in the 1940–62 period (based on all indicators used in the analysis, of course), in turn, is matched by a virtual parity in the growth of total factor productivity in the two countries. Also, although subject to certain qualifications noted earlier, we should note that the Soviet acceleration in the rate of technological progress in 1955–62 relative to preceding periods is paralleled by an improvement in the rate of growth in total factor productivity, whereas the decline in the U.S. rate of technological progress in the 1955–62 period compared to the decade following World War II is paralleled by a decline in the growth of total factor productivity relative to the decade prior to 1955.

There are two overriding conclusions to be drawn from the consistency of these findings.

The first, and of a very broad significance, is that although there are many factors that might affect the overall productivity of an economy at any given time, in the long run new technology is the force in even as diverse economies as the U.S.S.R. and the United States. Using the term "the force" I obviously do not intend to imply an exclusiveness of the contribution of technological change to productivity growth vis-a-vis other factors emphasized by the students of productivity, especially vis-a-vis education. Indeed, education, formal and informal, must be considered as a basic prerequisite of technological change. Yet it is possible that an economy, such as the U.S.S.R., might have a very rapid growth in the educational level

of the labor force and a very low rate of technological progress and a low rate of productivity growth.

In the light of what has been written about the importance of technological change for productivity growth before, this conclusion might sound trivial. Yet, the criteria I use in making the judgment seem to make the statement worthwhile.

The second key conclusion stemming from the consistency of these findings is that the "law of diminishing returns" is either not an important factor in productivity growth in either of the two economies or, if it is important, it has operated in both economies with about the same intensity.[62]

These two conclusions, on top of all other findings arrived at in the preceding two parts, have obviously many other implications, both specifically related to the two countries studied as well as of general analytical nature. Although I cannot hope to comment on all of them in this study, there are a few which can hardly be left unexplored. These are discussed in the three sections that follow.

THE APPARENT CAUSES OF THE GAP BETWEEN THE LEVEL OF PRODUCTIVITY OF THE SOVIET ECONOMY AND THE UNITED STATES

The observed dependence of productivity growth on technological progress suggests that the differences between the overall level of productivity of the Soviet economy and the United States should largely be a matter of relative technological advancement achieved by the two countries over time. However, commonsense dictates also that the differences in the resource endowment, factor proportions as well as the quality of the resource utilization might also be important factors in this difference. It is, of course, extremely interesting to know what role each of these four major factors plays in this difference and, if possible, why. Although the findings arrived at in the two comparisons cannot explain everything we wish to know about the causes of the gap, they furnish a significant part of the explanation.

With respect to the difference between the overall level of productivity of the Soviet economy and the United States, I refer to the discussion of the changes in the Soviet economy's position relative to the United States set forth in the last section of part IV and the corresponding numerical summary in table 7–II. There the conclusion was reached that in 1962 a dollar's worth of Soviet GNP required about 3.14 times as much labor input as in the United States and about the same and possibly 15 percent greater input of fixed business capital stock. If these average relative inputs are weighted the same way as the marginal rates in the factor productivity analysis (which is commonly not being done), the Soviet economy's dollar's worth of GNP

[62] At least on theoretical grounds it seems hard to believe that the "law of diminishing returns" is unimportant. If it were, the basic premise of economic theory would be a mere "empty box." More likely is the possibility that at the time under analysis this law has operated in both economies with about the same intensity. Such possibility seems plausible on the assumption that the intensity with which this law operates in an economy is a function of the rate of growth of the economy on one hand, and its level of development on the other. Due to the rapidity of overall growth this law has probably tended to operate with greater intensity in the U.S.S.R., but the level of development tended to make this intensity stronger in the United States. The net result is that the overall intensity has been about the same in both countries.

might be said to have required in 1962 (using 70–30 input weights) about 2.6 times as much aggregate prime input as in the United States, or that the overall level of Soviet economy's productivity in that year was only about 39 or 40 percent of that in the United States.

How much of this productivity gap can be attributed to the technological lag might be roughly approximated on the basis of the information as to the Soviet economy's prevailing use of new technology in 1962 relative to the United States in the past and the productivity effect of the technological progress made in the United States between that time and 1962.

As has been stated in the analysis of technological progress ("Pt. III: Summary view"), the scope of new technology used in the Soviet economy in 1962 was about on par with that used in the United States between 1939 and 1947, or the time of World War II. The technological progress made in the United States between that time and 1962 resulted in an increase in productivity of labor by about 50 percent, and an increase in productivity of capital by about 20 percent. (See table 4.)

We might presume, therefore, that if the Soviet use of new technology of 1962 had somehow been advanced to parity with that of the United States (and nothing else happened), the Soviet labor input requirement per dollar's worth of GNP would have been some 210 percent of the United States (314 divided by 1.5) instead of 314 percent; capital input, using the average, some 88 percent of the United States (105 divided by 1.2), instead of 105 percent; and the aggregate factor input about 190 percent of the United States, instead of actual 260 percent. In such a case the overall level of the Soviet economy's productivity relative to the United States would have advanced to about 52 percent, or be some 12 or 13 percentage points higher than it was in reality.

This reasoning leads to a conclusion that a full closing of Soviet economy's technological lag relative to the United States would be sufficient to close only one-fifth, or 20 percent, of its gap in the overall productivity. The other four-fifths (80 percent) of the productivity gap must therefore be attributed to factors other than technology. Beyond this, however, we must largely speculate.

Some part of the residual gap must undoubtedly be attributed to poorer resource endowment of the Soviet economy than the United States. Because of less favorable climatic conditions than in the United States the Soviet factories must probably be built more sturdily, the capacity of hydropower plants cannot be as fully utilized, and above all, agriculture is not as flexible and more frequently is plagued with deficient crop harvest. In addition, Soviet farmland is not as fertile, coal deposits often lie much deeper in the ground, etc. However, less favorable natural resource endowment alone can hardly explain all of the residual gap. If this factor were to explain a large proportion of the productivity gap, it seems improbable that this would not show up in a greater intensity of the "law of diminishing returns" in the U.S.S.R. than the United States. Some portion of the gap is probably caused by poorer factor proportions used in production. However, quite a bit of the gap, as shall become apparent in

the discussion of part VI, must also be caused by poorer utilization of the resources on hand. [63]

THE "MERIT" OF THE SOVIET ECONOMIC SYSTEM

The efficiency performance of the Soviet economy relative to the United States

The findings of the two comparisons also throw a considerable light on the relative efficiency capabilities of the two economies or what Professor Bergson defines as the question of the "merit" of the Soviet economic system.[64] In advancing this argument I should note that in view of the observed long-run dependence of aggregate factor productivity growth on technological progress as well as apparent absence of differential intensity of the "law of diminishing returns" in the two economies, the judgment on this question does not require reference to the relative productivity levels of the two economies (discussed in the preceding section), but may be based solely on the revealed relative "propensities" for making effective use of the opportunities for technological progress. For the benefit of those who seem to mistrust the inferences about the efficiency performance of the Soviet economy drawn from the Soviet economic variables constructed in Western style,[65] I should perhaps point out also that, because of the way I define the concept of technological progress, the judgment on this point does not even require reference to the growth of the (Western style) GNP or any other value aggregate.

By the concept of revealed propensity for making effective use of the opportunities for technological progress of an economy I mean the extent of the economy's actual achievement of technological progress compared with its apparent potentialities for such progress. This definition represents nothing more than appropriate paraphrasing of the conventional concept of demonstrated capability for economic "efficiency growth."

As already noted several times, in the 1939/40–62 period as a whole the Soviet rate of technological progress was about 60 percent of that in the United States, and between 1950 and 1962 it was about the same as in the United States when measured by all indicators, but only about 80 percent of the United States when only the contemporary indicators are considered. In terms of relative growth in total factor productivity, in 1940–62 the performance of the Soviet economy constituted about 80 percent of that in the United States, and about the same as in the United States in 1950–62. Thus in terms of both of these

[63] The preceding analysis may obviously also be stated in terms of the relative capital-labor and output-labor ratios rather than the labor-output and capital-output ratios as is one here. Such analysis, however, would require consideration of changes in quality of capital due to technological progress over much longer stretches of time than we have the information for. Moreover, the end results would probably be the same as stated in the text. As has been pointed out earlier, the Soviet ratio of the value of fixed business capital per person as well as the output (GNP) per person in 1962 were about the same as in the United States in 1890. The overall level of Soviet economy's technology in 1962, however, was on par with that used in the United States during World War II. Undoubtedly, the U.S. technology at the time of World War II was substantially more advanced than that used in 1890, or more than half the century earlier. Consequently, the Soviet output per person in 1962 should have been considerably higher than the U.S. output per person in 1890. That it was not higher can only be explained by poorer resource endowment and poorer utilization of the resources on hand.

[64] Cf. The Economics of Soviet Planning, op. cit., ch. 14.

[65] See, e.g., Edward Ames' review of Professor Bergson's book noted above in Slavic Review, December 1965, pp. 738–742.

indicators, the performance of the Soviet economy at best only approached that of the United States.

Considering all the principal determinants of technological change, however, the potentialities of the Soviet economy for both technological change and total factor productivity growth must be judged to have been vastly greater than those of the United States. This must have certainly been true, first of all, because U.S.S.R.'s substantially lower overall level of technology was undoubtedly offering opportunities for both faster rate of technological progress and faster growth in total factor productivity.[66] This must also have been true, secondly, because of the Soviet, on the average, almost three times as high a rate of growth of gross fixed business capital stock as in the United States. Inasmuch as new fixed business capital constitutes the indispensible "vehicle" of technological change, one might argue that on this account alone the Soviet economy's potentialities for technological progress were about three times as large as those of the United States. Thirdly, as has been noted in the analysis of technological progress, the proportion of engineers and technicians in the total employment of the Soviet industry was almost twice that in the United States. Since the average total employment in the Soviet industry for the 1940–62 period as a whole was about 10 percent higher in the U.S.S.R. than the United States, the total number of engineers and technicians in the Soviet industry was about twice that of the United States. In the economy as a whole the availability of graduate engineers increased from 290,000 in 1940 to 1.4 million in 1963, and that of "technicians" from 320,000 in 1940 to 2.4 million in 1963.[67] In my judgment, there is no reason to believe that with proper management and incentives, and given other advantages of the economy for such progress discussed here, this army of engineers and technicians in the Soviet economy could not have supported technological change at a rate much greater than in the United States. Nor, judging by the key indicators of technological change analyzed in the present study, would I consider it reasonable to believe that the availability of natural resources of the Soviet economy constituted a serious constraint for a much greater rate of technological progress than the United States had at the time. If there were any bottlenecks, the problems could have been resolved by only a modest increase in the volume of international trade. And, finally, there can be no question whatsoever as to the Soviet economy's greater potentialities for inexpensive borrowing of advanced technology abroad than those of the United States.

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[66] Although there might have been other forces that contributed to this result, it seems quite possible that the somewhat higher performance of the Soviet economy in terms of the rate of total factor productivity growth (80 percent of United States) than in terms of the rate of technological progress (about 60 percent) in 1940–62 was primarily the result of proportionately greater economic effectiveness of the same technological innovations in the U.S.S.R. than in the United States due to U.S.S.R.'s opportunities of skipping some stages of technological advancement relative to the United States. If this is the case I would define this phenomenon as "economies of backwardness." In order to be true it would have been merely required that, e.g., natural gas in the U.S.S.R. was being substituted for wood fuel, peat, shale, and poor coal, whereas in the United States for hard coal and oil; computers in the U.S.S.R. were replacing abacuses and human hands and pencils, while in the United States they were replacing the IBM punch card systems and desk calculators; tractors in the U.S.S.R. were replacing horses, and in the United States, older tractors; and the like.

[67] Cf V. E. Komarov, "Ekonomicheskie osnovy, podgotovki spetsiialistov dla narodnogo khozialstva" (Economic Foundations of Training Specialists for the Needs of the National Economy), Izdatelstvo Akademii Nauk SSSR, 1959, pp. 55–6, and Narodnoe Khoziaistvo, 1963, p. 487.

In the light of these considerations it seems sensible and even necessary to conclude that the Soviet economic system's propensity to make effective use of opportunities for technological progress and hence, efficiency growth, has been substantially weaker than that of the U.S. economy.

In stating this judgment I obviously do not intend to convey an impression that the U.S. economy represents an ideal economic system. Indeed, the persistence of excessive unemployment and the recurring evidences of monopolistic practices alone suggest that it is far from ideal. Yet, with all the efficiency inhibiting features that it has, there can be no doubt that in regard to doing things efficiently the U.S. economy has performed much better than the Soviet economy.

An addendum: The efficiency performance of the Soviet economy compared to major market economies

As an addendum to the preceding analysis, made possible by generous permission of Edward F. Denison to use his preliminary data on growth of gross fixed business capital stock in selected West European countries, it seems also appropriate to argue that the efficiency capabilities of the Soviet economy are inferior not only to the United States, but also to other developed market economies. For the basis of this proposition I refer to table 8 which compares the sources of economic growth in 1950–62 in selected West European countries, the United States and the U.S.S.R. in the same form as the comparison of the U.S.S.R. and the United States presented in table 6.

TABLE 8.—*Sources of average annual GNP growth in selected West European countries compared to the United States and the U.S.S.R., 1950–62*

Country	Average annual rate of growth in GNP and prime inputs (percent)			Average annual contribution to growth of GNP (70-30 input weights) (percentage points)				Ratio of average annual percentage point growth in GNP on account of factor productivity to percentage growth in fixed business capital stock (col. 7÷col. 3)
	GNP	Labor (man-years)	Fixed business capital stock (gross)	Labor (col. 2×0.7)	Fixed business capital stock (gross) (col. 3×0.3)	Total physical inputs (cols. 4+5)	Productivity (col. 1−col. 6)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
United Kingdom	2.6	0.7	3.0	0.49	0.90	1.39	1.21	0.40
Belgium	3.2	.5	2.9	.35	.87	1.22	1.98	.68
Netherlands	4.5	1.2	4.2	.84	1.26	2.10	2.30	.55
France	4.7	.6	3.6	.42	1.08	1.50	3.20	.89
West Germany	7.2	2.1	5.5	1.47	1.65	3.12	4.08	.74
Italy	6.1	1.5	3.6	1.05	1.08	2.13	3.97	1.10
United States	3.4	1.1	3.2	.77	.96	1.73	1.67	.52
U.S.S.R.	6.3	1.9	10.5	1.33	3.15	4.48	1.82	.17

NOTE.—The procedure and the assumptions used in the tabulation of this table are the same as set forth in the notes to tables 5 and 6.

Source: United States and U.S.S.R., table 6. Western European countries: GNP, United Nations, Yearbook of National Accounts Statistics, 1964, New York, 1965; employment, OECD, Manpower Statistics, 1950–62, and United Nations, Monthly Bulletin of Statistics, November 1964. Fixed business capital stock (gross): Preliminary estimates of Edward F. Denison prepared for his forthcoming book on sources of economic growth of Western Europe and the United States, used here in advance of publication with generous permission of the author.

Among the eight countries compared in the table the Soviet economy ranks second in terms of overall (GNP) growth, next to only West Germany; second in terms of growth of labor input, also next only to

West Germany; by far the very first in terms of growth of fixed business capital stock, followed by West Germany with only about half of the Soviet rate; fourth from the last in terms of total factor productivity growth; and by far the very last in terms of percentage-point growth of GNP on account of factor productivity per percentage increase in the gross fixed business capital stock.

From the point of view of efficiency performance of the various countries, the most important measures are obviously the ratios of the percentage point growth of GNP on account of factor productivity (total factor productivity growth) to percentage growth in fixed business capital stock since these, as noted in the discussion of part IV, reflect the economies' returns from the additions to the fixed business capital stock as well as the extent to which these economies make effective use of the opportunities for efficiency growth. In terms of this measure the Soviet economy's performance appears to have been roughly only two-fifths as good as that of the United Kingdom, about one-third as good as that of the Netherlands or the United States, about one-fourth as good as Belgium's, about one-fifth as good as that of France or West Germany, and only about 16 percent as good as that of Italy.

Of the eight countries compared, the most revealing is the comparison between the U.S.S.R. and Italy since these two countries, as has been noted earlier, presently have about the same overall level of productivity and resemble each other in several other important aspects except that Italy is smaller, has poorer natural resources, and is a market economy. As is shown in the table, in the 12 years covered by the data the overall growth of the Italian economy was roughly the same as that of the U.S.S.R., but Italy achieved this growth with only about 70 percent as rapid growth of labor input as the U.S.S.R.'s, and only one-third as rapid growth of fixed business capital input. The difference was made up by more than twice as high growth of productivity as in the U.S.S.R., and, as already noted, the Italian percentage growth of GNP on account of growth of productivity per percentage increase of fixed business capital stock was more than six times as high as that of the U.S.S.R.

The final point that should be noted in these comparisons is that the data for all countries show growing capital-labor ratios (index of average growth of fixed business capital stock divided by the index of growth of labor input), but the decline in capital productivity (index of average growth in GNP divided by the index of growth of capital stock) is evident only in the U.S.S.R. and slightly in the United Kingdom. The contrast with respect to capital productivity is especially great between Italy and the U.S.S.R. In the 12 years covered by the data the Italian capital productivity grew on the average by 2.9 percent per year whereas the U.S.S.R.'s was declining by 3.8 percent.

The cost of inefficiency of the Soviet economic system to the economy

In the light of the information presented so far and in part VI, there can be no doubt that the principal source of the comparative inefficiency of the Soviet economy is its sociopolitical system. Objectively this comparative inefficiency represents a cost to the economy, the cost of alternatives foregone. The specific magnitude of this cost

will, of course, be always a matter of speculation. A rough idea about the range of possibilities can be developed, however, by posing appropriate questions and figuring out the answers to these questions from the information presented so far.

To me the most reasonable question to ask for this purpose seems to be: How much capital could the Soviet economy have saved in 1950–62 had its growth in total factor productivity been 3.97 percent per year, as in the Italian economy, instead of the 1.82 percent it actually had, and if its GNP and labor input grew as they did?

In such a case the sources of the Soviet GNP growth would have roughly been as follows:

	Percent per year
GNP growth, total	6.30
Contribution of labor input (1.9 × 0.7)	1.33
Contribution of factor productivity	3.97
Necessary contribution of fixed business capital	1.00

Assuming a 30 percent weight for the capital input, as in the calculations of tables 6 and 8, a 1 percentage-point contribution of the capital stock to the growth of GNP would have required an annual growth of 3.3 percent, or about one-third of the actual rate.

With the required growth of 3.3 percent per year, the value of the Soviet gross fixed business capital stock would have increased from 63.3 billion rubles in 1950 to 93.4 billion in 1962, or roughly 30.1 billion. In reality it increased by 146 billion (from 63.3 to 209.3, as is shown in appendix C). Consequently there would have been a saving of almost 116 billion rubles (in purchasing power, equivalent to roughly 190 billion of 1958 U.S. dollars) which could have been used either to raise the standard of living or for investment. If invested, and assuming no technological progress to be embodied in this portion of the investment, the overall growth of the economy (GNP) would have increased to 8.5 percent, or some 34 percent over the actual. The composition of the GNP growth in this case would have been:

	Percent per year
GNP growth	8.45
Contribution of labor input (1.9 by 0.7)	1.33
Contribution of factor productivity	3.97
Contribution of fixed business capital stock (10.5 by 0.3)	3.15

For purposes of an alternative speculation we might arbitrarily assume that the Soviet economy's objective potentialities for technological progress in the 1950–62 period were twice those of the United States and that it utilized these potentialities in the same proportion as the United States. In such a case the Soviet economy's growth in total factor productivity would have been 3.34 percent per year, twice the U.S. rate (but smaller than the Italian). With such a growth in total factor productivity, and growth in labor input as it was, the actual GNP growth rate of 6.3 percent per year would have required growth in fixed business capital stock about 5.4 percent per year, or roughly the same as West Germany had at the time. In this case the savings of capital over the 12-year period would have amounted to about 80 billion rubles (equivalent to about 131 billion 1958 U.S. dollars) for

raising standard of living or investment. If invested, again assuming no technological progress to be embodied in this investment, the GNP growth rate would have increased to 7.8 percent per year, or about 25 percent above the actual rate.

Needless to say, this analysis represents an extreme simplification of the process of economic growth. Nevertheless the rough magnitudes of the cost of its sociopolitical system to the Soviet economy it indicates must largely be judged against the reasonability of the stated assumptions.

OTHER IMPLICATIONS

The findings of the two comparisons seem to have also two important purely analytical implications. Allusions to these have been made in the preceding discussion, but, because of their importance, it seems worth while to state them explicitly.

The first is that, contrary to frequently expressed views, an economy's rapid rate of growth in GNP does not automatically warrant the assumption of a rapid technological progress or rapid growth in factor productivity in that economy. Technological progress is a source of economic growth and not its result. As is suggested by the U.S.S.R. experience, an economy might have a rapid economic growth with rapid growth of physical inputs and a small growth of productivity. The Italian experience demonstrates that it is possible for an economy to have a rapid growth from a small growth of physical inputs and a rapid growth of productivity. The German experience suggests that a very rapid GNP growth requires both a rapid growth of physical inputs and a rapid growth of productivity.

The second general implication pertains to the apparent relationship between the rate of growth of fixed business capital and technological progress. Although technological progress presupposes new capital formation, a fast growth in capital formation of an economy can be used only as a measure of the economy's potentialities for technological change but not as a measure of the technological change itself. The Soviet performance demonstrates that an economy may have a very rapid growth in capital formation but very small growth in technological change and, hence, small growth in productivity. Moreover, the Italian and German experiences point out that the contrary is feasible. This obviously implies that generalizations about international trends in technological progress that are being made by economists on the basis of trends in capital formation and "average age" of capital assets (for example, machine tools) are unwarranted (although they might not necessarily be wrong). It also implies a serious reservation as to the usability of production function "embodiment" models not only for international comparisons, but also for studies of a single country over long stretches of time.

VI. The Principal Sources of Inefficiency in the Soviet Economy

The discussion in the preceding part has made it apparent that the two principal causes of the inefficiency of the Soviet economy both in relation to the United States and to developed market economies are low propensity for making effective use of opportunities for technological change (and, hence, productivity growth) and inefficient use

of the resources on hand. Both of these factors are obviously functions of the sociopolitical system in command of the economy. This conclusion is novel only in regard to the Soviet system's low propensity for making effective use of opportunities for technological change relative to the United States and relative to other developed market economies. The basic features of the Soviet system that inhibit efficiency growth, however, have been discussed in general terms in the press by many writers for a long time.[68] As pointed out by these writers, the most important of these features is the lack, or at least frequent disregard, of economic calculus in planning in general, and investment planning in particular (in the current critical Soviet parlance—"voluntaristic" decisionmaking) and poor business organization, including lack of proper incentives. To these a lavish cultivation of the "industrial defense establishment" should be added. I have little to add to the discussion on the subject matter in general terms. The discussion that follows, therefore, focuses largely on a number of specific examples of how these deficient features of the Soviet system actually work. The coverage must, of necessity, be sketchy. Each observation discussed, however, throws at least some light on the problem of concern to this study and the aggregate should considerably amplify the analysis set forth in the preceding parts.

"VOLUNTARISTIC" DECISIONMAKING

The most lucid example of "voluntaristic" decisions, one that probably contributed to the tardiness of Soviet technological progress and decline of capital productivity more than anything else, was Stalin's decision to base the Soviet industrialization almost exclusively on coal. S. D. Feld, an imaginative Soviet energy economist and apparently the protege of academician S. G. Strumilin, comments on the point in the following terms:

> What are the reasons for the fact that the structural changes in the energy balance of the U.S.S.R. ran contrary to the progressive trends in the energy field?
>
> The answer is only one. This was in response to the policy adopted in the period of the "cult of personality" which pursued the development of energy balance of the U.S.S.R. based on the predominant role of coal (including lignites and peat). This policy was rationalized at that time by a necessity to develop local energy resources wherever possible. However, this was being done without appropriate economic regard to labor, materials, and money expenditures needed for such development. Moreover, the saving of transportation cost accruing because of local supply of energy sources frequently was offsetting only an insignificant fraction of the additional cost and capital investment caused by unfavorable natural conditions and, most importantly, by low calorific content of the local energy sources.
>
> The predominant orientation of the economy's energy balance on coal was rationalized also on grounds that there were inadequate proved oil and natural gas deposits. However, even before the war it was generally known that the U.S.S.R. had some of the world's largest prospective deposits of oil and gas. If there was inadequacy of explored reserves of industrial significance, this was caused by inadequate expansion of geological explorations for oil and gas, and this, in turn, was caused by wrong attitude toward the development of energy sources needed by the country.[69]

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[68] Cf., e.g., Holland Hunter, "Planning of Investments in the Soviet Union," Review of Economic Statistics, 1949, No. 31, pp. 54–62; Abram Bergson, The Economics of Soviet Planning, op. cit., passim and particularly chapters 11, 13 and 14; and Alec Nove, The Soviet Economy, Frederick A. Praeger, New York, 1961.

[69] Cf. S. D. Feld. "Edinyi energeticheskii balans narodnogo khoziaistva (problemy optimizatsii)" (The Integrated Balance of Energy Sources of National Economy, Problems of Optimalization), "Ekonomika," Moscow, 1964, p. 54.

I realize the pitfalls of repeating the accusations of dead Stalin at the present time. Feld, however, appears to have a point. Between 1932 and 1937, the period when Stalin formulated and started implementing this policy, the Soviet proved reserves of oil (producing and prepared for production deposits) were growing at a rate of 8.7 percent per year, or 2.6 times as fast as the growth in actual oil production, the proved and apparent reserves grew at a rate of about 30 percent per year,[70] and the Soviet geologists were maintaining that—

* * * the overall reserves of oil in the U.S.S.R. (without Siberia) amount to 6.3 billion metric tons compared with 9 billion tons for the world as a whole * * * (and) on the basis of the entirely objective data one must with all certainty conclude that the Soviet Union has all the potentialities that are needed to become the largest oil producer in the world.[71]

Most of the oil sites classified in 1937 as apparent reserves are producing sites today.

In advancing this argument I do not intend to suggest that this policy was void of any rationale, but only that in terms of economic criteria it was not the best, and probably not even a second best, choice of alternatives imposed upon the economy by Stalin's will. Indications are that in formulating this policy Stalin was motivated by military considerations in anticipation of World War II and postwar conditions. This is suggested at any rate in a 1948 statement by V. N. Obraztsov, the Soviet railroads' senior spokesman on engineering matters. The statement reads as follows:

* * * the diesel-electric locomotive has one very great disadvantage: it requires liquid fuel. Comrade Stalin noted the desirability of having 60 million tons of oil per year in place of the 35.4 million planned for 1950. But we need oil for aviation, warships, automobiles, and tractors. It would hardly be expedient to replace all our steam locomotives by diesel-electrics. Besides, electric power from hydroelectric stations is much cheaper. From this, the desirable direction for our future power policy is perfectly clear.[72]

The policy has to a large extent survived to the present day. Production of oil and gas has been expanded relatively more than coal and peat, but the domestic use of oil has apparently been kept to places prescribed by Stalin: aviation, warships, and the applications where other types of energy would not do or technically are inconvenient to use. The rest is being exported.[73] In the field of transportation alone,

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[70] Cf. Prof. S. F. Fedorov, "Neftianye mestorozhdenila Sovetskogo Soiuza" (Petroleum Deposits of the Soviet Union), "Gosudarstvennoe Nauchno-Tekhnicheskoe Izdatelstvo Neftianoi i Gorno-Toplivnoi Literatury," Moscow-Leningrad, 1939, p. 532. I am indebted to Holland Hunter for this reference. Perhaps it will be instructive to note that at the turn of the century, the time the U.S. proved reserves of oil were about the same as in the U.S.S.R. in the late 1930's, the U.S. extraction of oil grew at the rate twice that of the growth of proved reserves. Cf. Historical Statistics of the United States, op. cit., Series M133–137, p. 360–1.

[71] Ibid., p. 531.

[72] V. N. Obraztsov, "Perspectivy elektrifikatsii zheleznodorozhnogo transporta v SSR" (Prospects for Electrification of Railroads in the U.S.S.R.), Moscow, 1948, pp. 15–16 as quoted by Holland Hunter in his "Soviet Transportation Policy," Harvard University Press, Cambridge, Mass., 1957 p. 125.

[73] In 1940 oil constituted 18.7 percent of the Soviet economy's total output of energy sources net of hydropower (calorific units), 17.4 percent in 1950, 21.1 percent in 1955, 26.3 percent in 1958, 34.2 percent in 1962, and 34.8 percent in 1963. Net exports of oil constituted about 2.9 percent in 1940, and in 1950 the U.S.S.R. had a net import of oil products amounting to 4.6 percent of domestic output. After 1950, however, net exports started to grow at a very rapid pace: 5.2 percent of output in 1955, 12.8 percent in 1958, and 23.9 percent in 1962. Cf. Narodnoe Khoziaistvo, 1958 and 1962, pages, respectively, 200 and 152; and Vnieshnaia Torgovla SSSR, editions for 1939–40 and 1955–62.

production of steam locomotives was not curtailed until 1956,[74] and their use will most probably be not eliminated for many years to come.[75]

This policy has had immense repercussions on the rate of technological progress as well as the capital requirement needed for industrialization. The sectors most severely affected by the policy are the mineral fuels industry, ferrous metallurgy, and freight transportation. As shown in table 9, the fixed capital in those sectors grew much faster than the growth of GNP, which undoubtedly contributed greatly to the decline of capital productivity in the economy as a whole.[76]

TABLE 9.—*Selected indexes bearing on the decline of capital productivity in the Soviet economy, 1940–62*

[1940=100]

Type of index	1940	1950	1955	1962
I. Indexes of fixed business capital stock (gross) in use of—				
(1) Mineral fuels industry	100	148	174	319
(2) Ferrous metallurgy	100	148	251	539
(3) Transportation and communications [1]	100	124	206	286
II. Indexes of output in the three industries:				
(1) Mineral fuels (kilo-calories)	100	131	202	328
(2) Ferrous metallurgy (steel ingot tonnage)	100	149	247	416
(3) Transportation:				
(*a*) Freight ton-miles	100	146	239	434
(*b*) Passenger-miles	100	92	160	280
III. Indexes of capital/output ratios in the three industries:				
(1) Mineral fuels	100	113	86	97
(2) Ferrous metallurgy	100	100	102	130
(3) Transportation:				
(*a*) Freight [2]	100	85	86	66
(*b*) Passenger [2]	100	134	129	102
IV. Indexes of GNP per unit of capital stock in use of—				
(1) Mineral fuels industry	100	84	99	81
(2) Ferrous metallurgy	100	84	69	48
(3) Transportation and communications [1]	100	100	83	90

[1] As of the beginning of 1964 capital stock of communications constituted only 5.6 percent of the total of transportation and communications. In preceding years this percentage was probably even smaller.
[2] Index of all capital stock divided by the index of respective transportation output.

Sources: Capital Stock: Promyshlemost SSSR, ed. 1957 and 1964, pp., respectively, 17 and 68–69; Narodnoe Khoziaistvo, 1963, p. 55. Output: Narodnoe Khoziaistvo, 1963, pp. 145, 150, 373–374 and table 4 (GNP).

[74] Narodnoe Khoziaistvo, 1958, pp. 240–241. The curtailment of production of steam locomotives was by no means a simple proposition. In 1954, 2 years before the curtailment, the plan for technological progress in the railroad industry called for production of three types of steam locomotives and one type of diesel locomotive. The diesel locomotive was intended to be used only on roads lacking water supply and heavy freight and passenger transportation. The pressure to get by with steam locomotives, however, was apparently well underway at that time. L. M. Kaganovich, one of Stalin's and Malenkov's most important lieutenants, stated his view on the point as follows: "I am for steam locomotives, I am against those dreamers who say that we will not use steam locomotives. These are strong machines, dependable and will not give up * * *." Following that, in 1955, there was an exhibition of technological achievements of the railroad industry in which the steam locomotives of the "future" were shown. In 1956 came the end to the production of steam locomotives and in 1957 Kaganovich became an "enemy of the party. Cf. L. M. Kaganovich "Uluchshyt' rabotu i organizirovat' novyi pod'em zheleznodorozhnogo transporta" (To Improve the Operations and Organize the Advancement of Railroad Transportation), Gospolitizdat, Moscow, 1954, pp. 69–70 and I. G. Kurakov. "Tekhnicseskii progress i rost proizvoditelnosti truda." (Technical Progress and Growth of Labor Productivity), Gospolitizdat, Moscow, 1956, p. 5. The credit for the interesting role of Kaganovich in the dispute goes to Holland Hunter.

[75] The relative shares of steam locomotive traction power in total Soviet railroad freight traffic on main lines were: 97.9 percent in 1940, 94.5 percent in 1950, 85.9 percent in 1955, 73.5 percent in 1958, 38.2 percent in 1962, and 29.3 percent in 1963. Cf. Narodnoe Khoziaistvo, 1958, 1962, and 1963, pages, respectively, 553, 385, and 374. The last steam locomotive was retired from line haul service in the United States early in 1960.

[76] Aganbegian, in his clandestine speech noted earlier, commented also on the point under discussion here. His statement reads:

"* * * we produce more coke than the United States but we use three times as much to produce a ton of steel. The metallurgical industry is not converted to the use of gas (there are not enough pipelines, but above all, there is insufficient willingness to do it and economic confusion) so that we are developing a coal industry which swallows up enormous funds" (Cf. the ASTE Bulletin, op. cit., p. 3).

Quite a few decisions have probably been made also on the basis of engineering considerations alone. A very good example of such decisions is the development of the electric steelmaking facilities (without adequate scrap base) and the neglect of the converter process. Reference to this decision was made in the analysis of technological progress. In this decision the rationale must have been that one can produce substantially better steel by means of electric steelmaking processes (arc or induction) than (Bessemer) converter processes. Any electric steelmaking process, however, requires some three times as much capital per ton of output as does the converter process. In addition, the bulk of the Soviet economy's demand for steel is undoubtedly of the kind that converter steel would suffice.

The policy of heavy emphasis on hydropower development analyzed earlier was probably also formulated largely on the basis of engineering considerations or, as alluded to in the Obraztsov's statement quoted earlier, by Stalin's command. As stated earlier, however, the presently available data do not seem convincing that in terms of total cost considerations this particular policy has been irrational, or at least as irrational as has been implied in the Soviet and Western press.[77]

The decision to develop the "virgin lands" was probably also of a "voluntaristic" nature and undoubtedly greatly contributed to the decline of capital productivity in the Soviet economy. However, the paucity of data to this effect at the present time does not permit going beyond the mention of this possibility, and perhaps it is still too soon to do so.

BUSINESS ORGANIZATION

Poor organization of the "civilian" technological research and development structure

Poor organizatioin of the "civilian" research and development structure must probably be ranked next to only "voluntaristic" decision-making as a factor detrimental to technological change. In most of the time covered by the present study the bulk of the experimental work with new technology, including design of new machinery and equipment, was done in the U.S.S.R. in specialized independent from industry central organizations (experimental design bureaus, or scientific research and design institutes) usually located far away from the plants that manufacture the products or in regional subsidiaries of these central organizations located near large machine building plants

[77] In the analysis of technological progress we concluded that in the area of electric power production and transmission the rate of Soviet technological progress was about the same as that of the United States despite the heavy stress on hydropower in the U.S.S.R. In contrast to the low-progress ferrous metallurgy, capital productivity in this high-progress area has increased as shown below:

	1940	1950	1955	1958	1962
Index of output (kilowatt-hours)	100	189	352	528	784
Index of fixed capital	100	152	318	487	690
Output/capital ratio	100	124	111	108	114

(Cf. Promyshlennost SSSR, ed. 1957 and 1964, pp. respectively, 17 and 68–69.) The growth in capital productivity in this sector would most certainly have been greater had there been a greater emphasis on thermal power.

but independent from them. Only very large plants have done some of their own designing. Most of the centralized design organizations lack or have only inadequate experimental manufacturing and testing facilities and must rely on services of regular production plants; this obviously protracts their work. The design departments in individual plants are, as a rule, concerned with improvements in the products currently produced and corrections of the designs made by centralized organizations rather than with designs of new products of their own.

As a result of this organization, the cost of the development has been very high, progress has been very slow and quality low. A knowledgeable Soviet writer recently complained about the situation in the research and development setup for agricultural machinery in the following terms:

> The development of many badly needed agricultural machines takes frequently from 6 to 7 years. In spite of this every year up to 60 percent of newly designed and built prototypes of such machines are being rejected in the experimental tests because of poor quality. In order to curtail these deficiencies it is necessary to exert a continuing care for reduction of the length of time required for design and "mastering" of production of new items of agricultural equipment, for improvements in the quality of designs, and for strengthening the manufacture-experimental basis of design organizations.[78]

The conditions probably vary somewhat from sector to sector of the economy. Even in such high-priority segment of the Soviet economy as the machine tool industry, however, the development cycle of a new machine ranges from about 5 to 6 years,[79] and the cost of development is exorbitantly high. A Soviet student of the economics of new product development in this high-priority industry comments on the point as follows:

> The most adverse factor affecting the cost of new products is inadequate preparation of technical documentation of the designs and their poor quality. The plants usually get the designs in unfinished form, requiring many changes and corrections which, in turn, increases the cost. The result of this is that, for example, the actual cost of a machine tool, model 5–A26, the manufacture of which was undertaken by the Saratov plant for gear-cutting machine tools in 1955, exceeded the preliminary estimate by eight times. The analysis of individual plants data shows that the actual costs of almost 85 percent of all newly developed products were higher than the estimates.[80]

Discriminatory pricing in capital goods

Of all the efficiency-inhibiting features of the Soviet economic system analyzed in the Western press, the Soviet price system has naturally been the prime target of the investigations.

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[78] L. A. Korbut (deputy chairman of the All-Union Society for Advancement of Agricultural Technology "Soiuzsel'khoztekhnika"), "Resolutions of the February Plenum of the Central Committee of the Communist Party of the U.S.S.R. and the Tasks of the Machine-Building Industry," Vestnik Mashinostroenia (Journal of Machine-Building), April 1964, p. 6.

[79] See I. Fofanov, "Nekotorye voprosy stimulirovaniia proizvodstva i vnedreniia novoi tekhniki" (Some Problems of Stimulating Production and Introduction of New Industrial Equipment), Voprosy Ekonomiki No. 6, 1959, pp. 14–21, and A. Miagkov, "Tekhnicheskii progres i moralnyi iznos oborudovaniia v SSSR" ("Technical Progress and Obsolescence of Equipment in the U.S.S.R.), "Vysshaia Shkola" (School of Higher Education), No. 1, 1960, p. 12. My informal inquiries with leading U.S. machine tool and agricultural implement manufacturers, as well as the information that is available in the press, lead me to believe that the development cycles of new products in the United States are probably about half as long as those in the U.S.S.R.

[80] I. Usatov, "Sebestoimost' i rentabel'nost' v mashinostroenii" (Cost and Profitability in the Machine-Building Industry), "Rezervy povysheniia rentabel'nosti machinostroitel'nykh predpriiatii" (Reserves for Improvements in Profitability of Machine-Building Plants), Moscow, 1957, p. 34.

The broad discriminatory features of the Soviet prices, such as prices for farm goods versus industrial products, prices for consumer goods versus capital goods, etc., are well known. So far, however, very little has been written on discriminatory pricing practices within major categories of goods, and virtually nothing about such practices within the area of capital goods. However, they do exist, in large measure represent deliberate policy, and are undoubtedly detrimental to the economy's technological progress in a genuine sense of the term.

The underlying philosophy, presumably laid down as far back as the 1930's, appears to be that capital goods favoring "technological progress" should have low prices (apparently below cost) and those that are "neutral" to technological progress should be priced at cost or higher.[81] For purposes of this price policy, however, technological progress does not seem to be defined as factor augmenting innovations but as production capability in accordance with priorities laid down in the industrialization plans. In terms of this antiquated concept, for example, any metal-cutting machine tool "embodies" technological progress, but a farm tractor does not. Needless to say, from the point of view of efficiency growth of the economy there can hardly be any more fallacious proposition than that.

For the sake of simple curiosity I have tried to figure out the probable impact of this policy on prices of automobile products, agricultural equipment, electrical machinery, machine tools, and turbines and generators. For this purpose I used Abraham Becker's 1955 U.S.–U.S.S.R. price ratio's adjusted for the U.S. price changes through 1958 [82] (for all industrial equipment and the four subgroups), my own overall price ratio for machine tools,[83] similar price ratios for industrial materials,[84] my estimates of the U.S.–U.S.S.R. ratios of labor and material inputs used in production of these equipment groups,[83] the pertinent cost breakdowns, and an assumption that the U.S. prices of these equipment groups are competitive (clearly a "heroic" assumption for at least one group).

The calculations based on these data and the stated assumption seem to suggest that in 1958 the Soviet prices of automobile products were some 20 or 25 percent higher than cost, and prices of agricultural equipment some 10 to 15 percent higher; but prices of metal-cutting machine tools and electrical machinery were some 50 percent lower than cost and those of electric turbines and generators lower than cost by some 65 or 70 percent.

It goes without saying that the margins of error in such calculations may be very large. Yet the basic propositions these figures suggest do not seem to be void of meaning. The practice represents simply a rationing tool for capital investment in priority and nonpriority sectors of the economy and its effects are undoubtedly inhibiting the efficiency growth of the economy.

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[81] Allusions to this philosophy may be found in virtually all Soviet publications dealing with prices, particularly in works by I. P. Aizenberg, V. D. Belkin, V. P. Diachenko, I. S. Malyshev, Sh. Ia. Turetskii, and A. Bachurin.

[82] Abraham S. Becker, "Prices of Producers' Durables in the United States and the U.S.S.R. in 1955," Rand Corp., Report RM–2432, 1959.

[83] Taken from my previously cited study, "The Soviet Challenge to U.S. Machine Building."

[84] 1955 Ruble-Dollar Price Ratios for Intermediate Products and Services in the U.S.S.R. and the U.S., CIA/RR ER 60–16, June 1960.

These discriminatory prices reflect the policy of the Gosplan of the U.S.S.R. which sets the long-range prices of industrial equipment. The individual ministries and other agencies which have jurisdiction over the factories that manufacture industrial equipment, however, have had the prerogative to set temporary prices of new products. In an effort to recover the cost of development (and correction of initial "bugs") in as short period as possible the latter agencies have aways tended to set the prices at such high levels that the prospective users frequently preferred the older similar products.[85] In 1959–60 an attempt was made to correct this malpractice. From 1961 on new products were to be priced at the level of similar old products with only small upward correction for the visually apparent superiority of the new products, and the cost of development had to be covered from a special development fund.[86] As of the end of 1964, however, the old practice appeared to have still been commonplace.[87]

Disproportionalities in the supply of capital goods

Apart from price discrimination (a tool of capital rationing consistent with overall priorities) there are also certain "rationing type" disproportionalities in the actual supply of capital equipment. In general, the production of equipment used in "direct production" operations seems to have enjoyed a higher production priority than equipment used in so-called "indirect" or "auxilary" operations. The large mass of available information seems to suggest that the production of material handling equipment has had the lowest priority possible. Since the performance of most "direct production" equipment usually depends on complementary auxiliary equipment, the discrimination against the auxiliary equipment tends to lower the performance of "direct production" equipment. If the new production equipment items that continuously are being added to the economy's capital stock are potentially more productive than the old ones and cost more money but their potential productivity is not being utilized, the result must be a decline in the economy's overall capital productivity.

The extent and rigidity of adherence to this policy might be judged by the following quotation that describes the situation in the steel industry, one of the highest priority sectors of the economy:

> It should be pointed out that even new designs of metalurgical enterprises do not provide for mechanization of auxiliary processes. The Magnitorgorsk metallurgical combinate currently builds a very large sheet rolling mill "2500" which shall produce sheet metal in rolls and sheets up to 2,350 millimeters in width and 1.5 to 10 millimeters thick. When completed, this mill will almost double the country's capacity to produce sheet metal of that type. Yet the design of this highly productive mill does not include mechanization of such auxilary operations as binding of hot-rolled rolls, packing of the rolls and sheets, etc. In advanced foreign countries these operations are mechanized.[88]

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[85] See, e.g., I. Fofanov, op. cit. and V. Ganshtak and V. Gotlober, "Materialnoe pooshchrenie proizvodstva i vnedrenile novoi tekhniki" (Financial Stimuli of Production and Introduction of New Technology), Voprosy Ekonomiki, No. 5, 1960, p. 64.

[86] A. Miagkov, op. cit., p. 12, and A. Gogoberidze and G. Ivanov, "Fond osvoieniia i tseny na novoiu tekhniku" (Fund for Development and Prices of New Equipment), Planovoe Khoziaistvo, No. 10, 1963, p. 26.

[87] Ia. Kvasha and V. Krasovskii, "Kapitalnoe stroitelstvo i problema vozmeshchenilia" (Capital Formation and the Problem of Replacement), Voprosy Ekonomiki, No. 11, 1964, pp. 12–13.

[88] I. V. Maevskii et al., "Mekhanizatsiia i avtomatizatsiia—osnova rosta proizvoditel'nosti truda" (Mechanization and Automation: The Prerequisite for Growth of Productivity of Labor), Gosplanizdat, Moscow, 1960, pp. 24–25.

Essentially the same effect is obtained when a plant receives two or more pieces of equipment from different producers for the same purpose but which do not perform equally well, or when a plant receives basic equipment from one producer and auxiliary from another and the two equipment items do not quite correspond, or if a new highly productive equipment item is added to old and less productive equipment. Such situations seem to be commonplace. I. G. Kurakov, quoted earlier, comments on the point as follows:

* * * In the last several years there has been an intensified mechanization of the coal mining industry. The industry is being equipped on a large scale with combines, loading machines, transporters, winches, and other equipment. However, all this new equipment was added to the old technology. The results of the mechanization proved to be highly inadequate. The old technology does not permit a full utilization of the new machines. The new machines idle most of the time. For example, the combines are being used only 4 to 5 hours for 24 hours of work in the mines, and loading machines only 1.5 to 2 hours.[89]

Haphazard planning of production and distribution of capital goods

Capital equipment, whether for an entirely new plant or for a new product in an old plant, is usually needed in sets of various types of items, and the capacity of each type should be in certain proportion to the others to permit an efficient utilization of the capital invested. The proportions greatly vary depending on the product to be made. As a rule, the greater the variety of equipment and the greater the number of capacity sizes in each type (type sizes in Soviet parlance) available the easier it is for the user to order the set that will best suit his need.

For the sake of savings in manufacturing costs and with apparently little regard to the users' cost, however, the Soviet planners have for some time now pursued a policy of cutting down on the number of type sizes whenever possible.[90] Moreover, the plants, having incentives to overfulfill the quantity plan targets, seem to have been producing some items, particularly those with which they have had greater experience or which can be manufactured by mass production techniques, in excess of genuine demand and other items, usually more complicated, in quantities much less than the genuine demand. The distribution system being, as in the area of consumer goods, a mere extension of the production system, distributes what it gets from manufacturing plants. The result is that the industrial plants usually have certain types of capacity much in excess of their need (and do not use them) and inadequate capacity of other types. Moreover, there seems to be no clear-cut pattern as to where and which types of equipment tend to be prevailingly excessive and which deficient. For example, a study of 46 Moscow machine building plants published in 1963 concluded:

In many enterprises, especially in machine tool plants, there is a disproportionality between the universal type of metalcutting equipment and special tools. Those plants, while having huge excess capacity in lathes, turning machines, and planers, have inadequate capacity in vertical forming, radial drilling, horizontal boring, jig boring, cylindrical grinding and suface grinding machines. Year after year the deficiency in supply of these machines keeps increasing and

[89] Cf. I. G. Kurakov, op. cit., pp. 8–9.
[90] Cf., e.g., G. I. Samborskii, "Avtomatizatsiia i spetsializatsiia v promyshlennosti SSSR" (Automation and Specialization in Soviet Industry), Moscow, Izd. "Mysl," 1964, p. 183.

this constitutes a drag on utilization of other machines and thus lowers the productive capacity of the plants. [91]

At the same time, however, in the machine building plants located in the city of Lvov (West Ukraine), the situation was a reverse of that in Moscow. The pertinent conclusion of a study reads as follows:

> The people working in the machine building industry know very well that the structure of industrial equipment produced in the economy and the system of distributing the equipment by plants should be changed and improved. After redistribution of excess (superfluous) machine tools by production departments, shops and plants, the balance showed that there was a 50 percent deficiency in lathes and turning machines, 10 percent in boring machines, 18 percent in automatic lathes, and 10 percent in presses. At the same time, there were excess grinders, drilling machines, gear cutters, broaching machines, cold upsetting machines, and like. [92]

Poor quality of capital equipment

According to an authoritative source, 90 to 100 percent of all "technological" equipment used in the Soviet economy is repaired every year, 20 to 25 percent undergoes medium-type overhaul, and 11 to 12 percent a complete overhaul.[93] In addition, there is no centralized supply of spare parts, except for such mass produced items as automobiles, agricultural tractors, etc., and even this apparently very poor.[94] Whenever needed spare parts for nonmass produced equipment items have to be manufactured at the place of their use, and this usually by very primitive techniques. In such conditions equipment might easily be tied up for two or even more months every year in repair and not work really well the rest of the time. For a Soviet industrial plant or any other similar economic organization to function smoothly, it must have a large reserve capacity of all essential equipment as well as a large repair crew. As a result, the equipment maintenance and repair workers constitute by far the largest single skill category of workers in the U.S.S.R. economy. In 1958, the latest year to my knowledge for which such estimate was made, their number in all sectors of the Soviet economy was about 3.2 million,[95] which was equivalent to about 6 percent of total nonfarm civilian employment of the economy, or as much as 58 percent of the total employment in the machine building industry.[96]

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[91] K. Kogan, "Chto pokazal analiz" (What Showed the Analysis), Planovoe Khoziaistvo, No. 7, 1963, p. 72.

[92] A. Sidorov, "Polnostiu zagruzhat' oborudovaniie v mashinostroenii" (On Fuller Utilization of Equipment in Machine-Building), Planovoe Khoziaistvo, No. 7, 1963, p. 64.

[93] "Edinaia sistema planovo-preupreditelnogo remonta," op. cit., p. 7.

[94] Cf., e.g., M. Markin, "Iz opyta raboty statisticheskogo upravleniia ukrainskoi S.S.R." (Some Work Experiences of Statistical Administration of the Ukrainian S.S.R.), Vestnik Statistiki, No. 2, 1957, p. 66.

[95] Cf. S. A. Kheinman, "Organizatsiia proizvodstva i proizvoditelnost truda" (Organization of Production and Productivity of Labor), Moscow, Gosplanisdat, 1961, p. 27 and 25–76. It might be of interest to note also that Kheinman's estimate of all equipment repair workers for the United States in 1958 is 1,200,000, or roughly 38 percent of the number in the U.S.S.R. See ibid., p. 27.

[96] In 1958 total nonfarm civilian employment in the Soviet economy was 53,800,000, and the total employment in the machine building industry about 5,600,000. (Cf., respectively, "Annual Indicators," 1964, op. cit., p. 63 and "The Soviet Challenge," op. cit., p. 41.) In the "clandestine" speech, Aganbegian made also a statement with respect to capital utilization and repair. The pertinent passage reads as follows: "* * * Our productive capacity, which to tell the truth isn't really so good, is not utilized to any more than 70 percent of capacity. * * * The number of machine tools we have is equal to the number in the United States but only half of ours produces effectively while the others either are not used or are being repaired. We employ more workers to do repair work than to produce new machines. The basic funds for production are utilized worse by us than in capitalist countries. Productive potential (output capacity) is utilized by us in a fearfully inadequate way in the mechanical sector." (Cf. The ASTE Bulletin, op. cit., p. 2.) This observation, too, is basically in accord with my findings set forth in the present

Although it is not known whether the haphazard planning of production and distribution of capital goods and the quality of these goods, as well as other similar factors to be mentioned somewhat later, had been worsening over the period covered by this study, and, hence, contributing to the observed decline in productivity of capital, it is unquestionable that they tended to depress the effective utilization of all equipment stock available in the economy and, hence, the level of output per ruble worth of fixed business capital stock "on the books." A sizable portion of the ecomony's equipment stock does not work because it is out of order or being repaired, some portion does not work because it is of the wrong type for purposes of the plants in which it happens to be placed, and some, as will be pointed out shortly, does not work because people do not have the incentive to use it.

Although the available data do not permit me to quantify the aggregate effect of these factors upon the use of capital in the Soviet economy as a whole, an illustration of what this effect might be in at least the metalworking sector is provided in table 10.

TABLE 10.—*A comparison of normative and actual average annual hours of work of equipment in eight metalworking plants in the city of Ivov*

Plant	Metal cutting machine tools			Metal forming machine tools		
	Normative hours	Actual hours	Actual as percent of normative	Normative hours	Actual hours	Actual as percent of normative
Bus plant:						
Prefabricating shop	4,095	1,014	24.8	4,095	3,296	80.5
Machine shop:						
Turning department	4,095	1,919	46.9	----------	----------	----------
Parts department	4,095	2,261	55.2	----------	----------	----------
Fittings plant	6,075	2,330	38.4	----------	----------	----------
Motorcycle plant	4,095	1,480	36.1	4,095	2,080	50.8
Machine building plant	6,075	3,101	51.0	----------	----------	----------
Milling machine plant	4,095	1,940	47.4	----------	----------	----------
Tool and accessories	4,095	2,176	53.1	----------	----------	----------
Agricultural equipment plant	6,075	4,694	77.2	----------	----------	----------
Plant for auto loaders	4,095	1,500	36.6	5,996	4,470	74.5

Source: A. Sidorov, "Polmostin zagruzhat'oborudovaniie v mashinostroenii" (On Fuller Utilization of Equipment in Machine Building), Planovoe Khoziaistvo, No. 7, 1963, p. 64.

This table gives a comparison of normative and actual hours or work of equipment in eight Soviet metalworking plants in the city of Lvov, to which I referred earlier. Since the Soviet "normative hours" might be interpreted as a maximum for a normal work regimen (number of shifts) of the plants, these data actually reflect the extent of "normal" capacity utilization. As shown in the table, the

and preceding (The Soviet Challenge, op. cit.) studies. According to my calculations, however, one correction in Aganbegian's observation seems to be in order. He states that "We employ more workers to do repair work than to produce new machines." He should have said: "We employ more workers to do repair work than we employ direct production workers to make new machines." As noted in the text, in 1958 the number of repair workers in the Soviet economy was about 3.2 million; the total employment in the machine building industry 5.6 million, and the number of direct production labor in that industry about 2.1 million. (38.2 percent of the total. Cf. The Soviet Challenge, op. cit., p. 44.) Thus, the number of repair workers was equivalent to 58 percent of total employment of the machine building industry, but about 50 percent larger than the number of direct production workers. These percentage relationships could not have changed much since 1958. Aganbegian's inaccuracy might obviously be due to "oratory," inaccurate transcription or faulty translation.

utilization of metalcutting machine tools in all eight plants ranges from a low 24.8 percent to 77.2 percent, and the average is close to 60 percent. I should note that metalcutting machine tools constitute the principal "direct production" equipment in metalworking plants as well as in the industry as a whole and, as pointed out in the analysis of technological progress, are very popular and relatively abundant in the U.S.S.R. The utilization of metalforming machinery used in only three plants, in turn, ranges between 50.8 and 80.5 percent, and the simple average in close to 70 percent. As noted also in the analysis of technological progress, metalforming machines in the U.S.S.R. are less popular and more scarce.[97]

Lengthy construction of new plants and reconstruction of existing enterprises

In sizable measure the observed decline in capital productivity has been caused by the rapidly growing magnitude of unfinished construction on the one hand, and losses of production because of vast programs of reconstruction and expansion of existing enterprises on the other hand.

The value of unfinished construction in state and cooperative enterprises and organizations increased from 8.7 billion rubles in 1950 to 26.1 billion rubles in 1962, or 300 percent.[98] Although it is not known what proportion of this unfinished construction was for business uses, an assumption of a mere 50 percent would mean that some 6 to 7 percent of the total value of fixed business capital of the Soviet economy on the books in 1950 and 1962, and between those years, was not usable for productive purposes at all.

The probability is, however, that at least between 1959 and 1962 this percentage was substantially higher. The reason for this is that in 1959 Soviet planners launched a vast program of reconstruction and expansion of existing enterprises. Between 1959 and 1963, 50 to 60 percent of all the funds invested in the Soviet industry were used for such purposes.[99] A reconstruction of any existing plant must involve at least a partial idling of existing capital for the duration of the reconstruction. The nonuse, or "idling," of fixed business capital in the Soviet economy in the 1959–62 period (and 1963) must, therefore, have been even substantially greater than is suggested by the data on the unfinished construction.

Judging by the extent of the reconstruction involved in most projects and the length of time these probably will take, however, it would seem that the growth of "unfinished construction" will become a long-

[97] It is worth while to note that the average actual utilization of metalforming machinery relative to the normatives in the three plants shown in table 10 is very much in accord with the Aganbegian's description of the average capacity utilization of the Soviet economy (up to 70 percent), and how accurately the utilization of the metalcutting machine tools fits his description of even less efficient capital use in the "mechanical sector," reference to which was made in note 96 above. One must wonder, of course, to which extent these data might have influenced his conclusions.

It seems also appropriate to wonder whether or not there is any correlation between the efficiency of capital use in an industry and its ranking on the regime's priority scale. The "mechanical" sector has certainly always been high on the scale and apparently inefficient in capital use. So was the steel industry, and, to a large extent, the electric power generation industry (because of investment in hydropower projects).

If such low "capacity" utilization is as widespread in the Soviet economy as all these data seem to suggest, however, then the Soviet average (normal) "capacity utilization" would have to be rated no higher than what the United States experiences in such years as 1958 or even lower.

[98] Narodnoe Khoziaistvo, 1963, p. 460.

[99] Ibid., p. 456.

run phenomenon. For example, the "coefficients of renovation" envisaged in the reconstruction plans of 40 machine building plans, discussed recently in a publication of the Academy of Sciences, range between 39 and 90 percent, with an average of about 61 percent.[100] Construction in the U.S.S.R., and particular reconstruction, however, take a very long time. In regard to new construction Academician Khachaturov, who has been concerned with this problem for a long time, merely states that:

> Construction of plants and electric power stations in the U.S.S.R. takes many years. There are frequent cases of extensive prolongation of residential construction, when even building of a small house takes 1.5 to 2 years to complete.[101]

Reconstruction evidently takes even longer. In the past, the reconstruction of several well known plants had taken up to 14 years.[102] Even the plans for reconstruction of the 40 machine building plants mentioned earlier assume that the average length of reconstruction of 2 plants would take 2 years per plant; 12 plants, 3 years per plant; 13 plants, 4 years per plant; 11 plants, 5 years per plant; and 2 plants, 6 years, which adds up to an average of 4 years per plant.[103] In practice this average might easily become twice as long.[104]

It appears also quite probable that when this huge reconstruction program is completed it will prove not as effective as expected. In fact, a study of 46 newly reconstructed plants conducted by the Stroibank (Bank of Construction) in 1962 concluded that two-thirds of these plants had higher capital/output ratios than comparable new plants.[105]

Lack of proper incentives

In view of what has been written previously about the lack of proper incentives in the Soviet economy,[106] I need hardly do more than reemphasize the importance of this factor. Indeed, looking at it from the ontological point of view, one might argue that most of the deficiencies of the Soviet economic system pointed out earlier are attributable to the lack of proper incentives. In view of the fact, however, that human actions might be directed not only by natural motivations but also by command or force, it seems preferable to treat this factor in the context of business organization.

The three broad-based observations given below are believed to indicate the scope of the problem as well as the probable depth of its impact of concern to this study.

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[100] See Akademiia Nauk SSSR, Institut Ekonomiki, "Effektivnost kapitalnykh vlozhenii v razlichnykh otraslakh sotsialisticheskoi promyshlennosti" (The Effectiveness of Capital Investment in Various Branches of the Socialist Industry), Moscow, 1963, p. 95.

[101] Idem, "Kapitalnye vlozheniia i rezervy ikh ispolzovaniia" (Capital Investment and Reserves for its Utilization), Moscow, 1963 (article by Khachaturov), p. 11.

[102] See source noted in note 100, pp. 111–2.

[103] Ibid., p. 111.

[104] The reason for long construction cycles in the U.S.S.R. might also be of interest. On this Khachaturov notes that, "The advanced Soviet method of rapid construction, based on foreign experience, is being practiced inadequately * * *." (See source noted in note 100, p. 11). In addition to this, however, there are "deficiencies in planning and organization of construction, due to atomization of investment funds and material resources in many projects of construction and reconstruction, diversions of funds for other projects, untimely and incomplete preparation of design documentation, poor organization, and frequently poor workmanship on individual sites * * *." (See source noted in note 100, p. 112.)

[105] Ibid., p. 100.

[106] Cf., e.g., David Granick, "Management of the Industrial Firm in the U.S.S.R.," Columbia University Press, New York, 1954; Joseph S. Berliner, "Factory and Manager in the U.S.S.R.," Harvard University Press, Cambridge, Mass., 1957; Gregory Grossman, "Soviet Growth—Routine, Inertia and Pressure," American Economic Review, May 1960; and Alec Nove, "The Soviet Economy, An Introduction," Frederick A. Praeger, New York-Washington, 1966 (rev. ed.), chapter 6.

(1) In 1960, at that time the chairman of a southern regional economic council (*sovnarkhoz*) stated:

> * * * our plants have far too many engineers and technicians, 1 for every 12–15 workers, whose function is to keep records of fulfillment of normatives and plans by the workers. There is a need for a long overdue review of the work of engineering and technical personnel in order to increase their productivity. It would appear necessary to reduce the ratio of engineering and technical personnel to workers from 1 to 12–15 to 1 to 20 or 40 or 50 and to transfer the laid-off engineers to designing bureaus, research departments, experimental shops, laboratories, etc. These services are nonexistent in our plants or badly need strengthening and expansion. * * * This we cannot do because the pay of a shop engineer is substantially higher than the pay of an engineer-designer, researcher, or a laboratory specialist * * *.[107]

The situation in this particular region appears to have been far from unique. For example, at about the same time (1959 or 1960), a manpower survey made in the Moscow (regional) economic council concluded that the engineers and technicians in the chemical and electrotechnical industries of that region constituted about 25 percent of total manpower. Of the total number of the engineers and technicians employed in these industries, however, only 5.1 percent worked as engineers or technologists in a proper sense in the chemical industry, and 14.5 percent in the electrotechnical industry. All others worked in management.[108]

Although the Moscow survey does not state that pay was a factor in determining the small proportion of engineers and technicians working in their profession, we might presume so. In 1964, upon his return from a trip to Moscow Folke Halden of Sweden reported that the pay of Soviet engineers ranged between 100 and 300 rubles per month and that of managers between 300 and 1,000 rubles per month.[109] These pay scales could not have changed much between 1960 and 1963 or 1964.

Although in these observations the role of incentives is interwoven with poor organization of research and development, one might presume that more engineers and technicians would have preferred work in their learned profession rather than as "timekeepers" if the pay were "right." And if they had, the economy's rate of technological progress would have at least tended to be greater than it was.

These observations obviously indicate also that the Soviet economic system not only has problems with respect to efficient use of capital, but also with respect to the use of human talent as well as manpower at large.

(2) In a survey of "modernity" of product mix in 398 manufacturing plants in Moscow in 1960 a Gosplan study group concluded that only 60 percent of the products produced by these plants in that year measured more or less up to the standards of contemporary "know-how." The other 40 percent were found as over-obsolete and the production of these was ordered either to be dropped or the products to be modernized.

The reason for continued production of obsolete items was found to be management's lack of incentive to discontinue any production

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[107] "Spetsializatsiia i kooperirovanie promyshlennosti" (Specialization and Cooperation in Industry), Gosplanizdat, 1960, p. 183.

[108] "Organizatsiia upravleniia i planirovaniia promyshlennosti" (Organization of Management and Planning in Industry), Gosplanizdat, Moscow, 1960, p. 80.

[109] Folke Halden, "Tendencies in the Russian Economy; Labor Market and Education" in Ekonomisk Revy, edited by the Swedish Bankers Association, April 1964, p. 30.

they had "mastered" and which permitted them to show a good performance in terms of the familiar basic "success indicators": the quantity of output, percentage reduction in cost, and percentage increase in labor productivity.[110] Good performance in terms of these indicators obviously means rewards in the form of bonuses, security, prestige, etc.

Although such practices have been known for a long time, evidence that they were such a big detriment to technological progress as was discovered in the large sample of the plants located in the center (Moscow and its vicinity), had not been suspected.

It might be of interest to note also that the findings of this study played a major role in the decision to change the regulations with respect to pricing of new products, establishment of "development funds" in individual establishments, and changes in "incentive awards" regulation promulgated in 1960–61, reference to which was made earlier.

(3) The third observation refers to the attitude toward technological change, or rather the use of capital that probably constituted a considerable departure from customary techniques of doing things. Another Gosplan study, also made in 1959 or 1960, reports:

"* * * (There is) lack of appropriate understanding of the role of technological change on the part of some *sovnarkhozy* (regional economic councils). Thus, for example, in Arkhangelsk, Mariisk and Sverdlovsk *sovnarkhozy* no use was made of *imported* equipment for production of fiber-wood panels which they received as far back as 1951–1953.

An analoguous situation exists also with respect to the use of other *imported* equipment. In Arkhangelsk *sovnarkhoz* no use was made of imported bark-stripping machines, cable cranes, and *prototype* equipment for the warehouse operations; in Krasnoiarsk *sovnarkhoz*, no use was made of *imported* chainsaw installation * * *.[111] [Italic mine—M.B.]

This observation would seem to indicate the existence of a sort of "feather-bedding," and this, curiously enough, on the part of management. One must assume that in the U.S.S.R. the control over the use of imported equipment is more meticulous than that over the equipment allotted from domesic sources of supply. If such laxity exists with respect to imported equipment, the laxity must be considerably greater with respect to that of domestic origin.[111a]

Such examples of lack of proper incentives as the three cited could be continued almost infinitely, particularly if those pertaining to the operation of the Soviet agriculture were included. I cite none from the agriculture here on the assumption that for most readers they would be superfluous.

Inefficient use of industrial materials

In addition to the evidences of poor business organization affecting inefficient use of capital and manpower directly, the Soviet press is full of evidences indicating the inefficient use of the prime factors of production in an indirect way, notably through inefficient use of industrial materials. These are best exemplified by the inefficient use of metals, particularly steel.

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[110] Cf. Organizatsiia upravlenila, op. cit., p. 67.

[111] Cf. I. V. Malevskii et al., op. cit., pp. 59–60.

[111a] According to a source which became available to me shortly before this study went to print, 9.9 percent of all equipment "on the books" of the Soviet industry in 1960 was uninstalled, and by 1963 this percentage increased to 12.5 cf. source cited in part VII, note [124] below.

The probability of inefficient use of metals has been alluded to in the discussion of changes in the position of the Soviet economy relative to the United States in part IV and of the Soviet economy's productivity gap relative to the United States in part V. In these discussions we concluded that per unit (dollar's worth) of GNP the Soviet economy used about 96 percent as large quantity of basic metals as the United States in 1940, but by 1955 it exceeded the United States in the use of basic metals by about 17 percent, and by 1962 by about 60 percent (see table 7, sec. II). These relative inputs of basic metals, however, reflect the two countries' differences in product-mix and technology, as well as the inefficiency and there is no easy way to isolate the contribution of each of these three factors to the overall figure.

For the broad findings in which the impact of differences in product-mix and technology are much smaller I refer to the analysis of the comparative metal inputs per dollar's worth of machinery output in the two countries in 1958 presented in my earlier study. In that study I concluded that per dollar's worth of all machinery output the Soviet industry was using, on the average, about 40 percent more metal than the U.S. industry.[112]

The inefficiency with respect to industrial use is, of course, not limited to metals. The inefficient (excessive) use of metal alone makes it necessary to use also more fuel (to melt and heat treat the metal), more refractories needed in furnaces, more transportation facilities, etc.

THE ROLE OF "INDUSTRIAL DEFENSE ESTABLISHMENT"

I realize that in advancing the argument that the "industrial defense establishment" has been one of the principal sources of inefficiency in the Soviet economy, I might be exposing myself to a severe criticism. After all, most of technological innovations of the last 10 to 20 years, whether in the U.S.S.R. or the United States, have originated in these "establishments." One might obviously argue also that in many countries, including the United States, the defense establishment has frequently acted as "energizer" of economic activity, frequently much in excess of its own needs. Moreover, there is more to a country's well-being than economic efficiency.

I am not prepared to deny the validity of these reservations, at least not entirely. Yet I think I have a point, and a valid one, too. In advancing the argument I assume that if for a decade or two an economy's "industrial defense establishment" grows at the rate two or three times the rate of the economy as a whole, and if such rapid growth of the establishment is accompanied by as rapidly changing defense technology as we have witnessed in the last two decades or so, the minimum effects of this establishment's growth upon the economy as a whole will be:

(1) A continuous "siphoning" of best scientific and engineering talent from "civilian" economy into the defense-oriented sector. This tendency undoubtedly will adversely affect the economy's rate of tech-

[112] See "The Soviet Challenge to U.S. Machine Building," op. cit., pp. 15 and 20–21. See also note 76 above.

nological progress unless there is a large "spillover" of technological breakthroughs from the defense sector to the economy at large. Historically, however, this has yet to take place anywhere, including the U.S.S.R. and the United States.[113]

(2) Continued direction of capital investment to the defense establishment at the rate progressively greater than its growth because of high rate of equipment obsolescence in that sector, low adaptability of most obsolete equipment for uses other than originally designed, and relatively lax use of capital in this sector due to greater than in civilian economy need of standby equipment, greater use of equipment for rare or unique applications, greater emphasis on quality of the products, and the like. The result of this tendency must be a declining utilization of the capital "on the books" of the economy and, consequently, a decline in capital productivity, as we measure it.

As is generally known, there is very little readily available information on the Soviet "industrial defense establishment" and what is readily available cannot be easily interpreted. My judgment about the growth and the size of this establishment is based on my own estimates of the apparent acquisition of the products of the machinery (including electronics) industries [114] by the Soviet Government for purposes other than capital investment, sales to consumers, and exports in 1958, 1961, and 1963. Although the specific information to that effect is not available, there are good reasons to believe that some 90 to 95 percent of these acquisitions was probably for the defense and space programs, and the rest for the (nonproductive) use of the general government. The total values of these acquisitions in each of the 3 years in rubles and approximate U.S. dollar equivalents were: [115]

1958: 7.2 billion rubles ($19.8 billion, 1958 dollars);
1961: 9.6 billion rubles ($26.4 billion, 1958 dollars);
1963: 13.1 billion rubles ($36 billion, 1958 dollars).

Judging by these data the Soviet "industrial defense establishment" increased in the 5 years by 82 percent, or, on the average, 12.8 percent per year. This rate is 184 percent higher than the average for GNP (4.5 percent) and 71 percent higher than the growth in total industrial production (7.5 percent) at that time.[116]

The judgment as to whether the Soviet "industrial defense establishment," apparent in these figures, was large or small in an absolute sense must obviously depend on the size of such an establishment in the United States.

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[113] Of the many technological breakthroughs achieved in the defense research and development in the United States, profound economywide significance has been acquired only by jet aircraft, computers, and, possibly, numerically controlled machine tools. In the U.S.S.R., the "spillover" was even smaller. As noted in the analysis of technological progress, as of 1962 the Soviet use of computers and numerically controlled machine tools was, for all purposes, still limited to the "defense establishment."

[114] On what the Soviets include in the machinery industries (machine building) see "The Soviet Challenge," op. cit., pp. 2–3.

[115] The estimates represent the net value of output (defined as value added plus unduplicated cost of materials, fuels, and supplies) of all machinery and related products plus import surplus less the value of producers' and consumers' durables. The procedure, sources of information and the assumptions used in the estimating are explained in "The Soviet Challenge" table 3, p. 34. The figures for 1958 and 1961 given in table 3 of "The Soviet Challenge" were slightly increased to account for nonmachinery items (furniture) in the total values of machinery and equipment invested. In converting rubles into 1958 U.S. dollars I assume that the purchasing power of 1 ruble spent on these products was $2.75 per ruble, that is, the same as the average spent on all machinery which was estimated for the previous study (see ibid., pp. 35 and 49).

[116] Cf. Current Economic Indicators, 1965, op. cit., app. table 1, p. 20.

Because of a large U.S. foreign trade in machinery products, lack of data on "producers' prices" in years other than 1958, and substantial differences in the inventories of the U.S. manufacturers of machinery in different years with respect to business-cycles, a major research effort would be required to determine the estimates for the United States that would be exact counterparts of the estimates for the U.S.S.R., both in terms of methodology and content. A fairly close approximation of the growth and the size of the U.S. counterpart "establishment," however, is indicated by the official data on the net value of procurement actions by the U.S. Department of Defense and the National Aeronautics and Space Administration (NASA). The value of these procurements in the 3 years were: [117]

	Billion
Calendar year 1958	$21.3
Calendar year 1961	24.1
Calendar year 1963	29.5

A brief comment concerning these data is in order. Both the U.S. Department of Defense and NASA data cover the procurement from all industries but do not cover the value of the pertinent products produced in the Department of Defense's own facilities. Judging by the primary product specialization of the 100 largest contractors and the values of contracts awarded to them by the Department of Defense and NASA, it seems that some 10 to 12 percent of the total value procured were from nonmachinery and nonelectronic industries.[118] In order to compare these U.S. data with the Soviet figures, the value of the U.S. procurement from the nonpertinent industries would have to be subtracted from the totals. At least for 1963, however, just about the same value would have to be added to account for the value of pertinent products produced in the Department of Defense's own facilities.[119] As far as I know, because of the functional classification of the Soviet industry, strictly military industrial facilities in the Soviet Union are classified in the respective industries, and the value of their production is counted in the output of the respective industries.

These data indicate that the U.S. "industrial defense establishment" increased over the 5-year period, too, but only by 38 percent, or less than half as much as the U.S.S.R. The judgment concerning the comparative sizes of the two establishments depends somewhat on how great we assume the share of the Soviet military and space programs in the total Government acquisitions. Assuming the share is 90 percent, which I consider as a minimum, it would appear that the Soviet establishment was about 85 percent as large as that of the United States in 1958, about the same as the United States in 1961, and about

[117] The figures represent the sum of the net value of the procurement actions in the United States and possessions by the two agencies. The values procured by the Department of Defense (for each year it was necessary to average 2 years to convert fiscal year data into calendar year data) come from the Background Material on Economic Impact of Federal Procurement—1966, materials prepared for the Subcommittee on Federal Procurement and Regulation of the Joint Economic Committee, Congress of the United States, March 1966, p. 20. The NASA data are from its Annual Procurement Report, fiscal year 1965.

[118] Cf. ibid., pp. 26–32.

[119] Cf. U.S. Bureau of the Census, "Shipments of Defense-Oriented Industries," Special Report MC–63(S)–2, 1966, app. B. Ordnance, accessories, and ammunition are not being classified in the U.S.S.R. as "machinery" (they are metal fabricates), but missiles, aircraft, ships, automobiles, and all machinery in narrow sense are.

10 percent larger than the United States in 1963. If we assume that the share of military and space programs' acquisitions represent about 95 percent of the Soviet total, the relative size of the Soviet establishment increases proportionately; that is, to about 90 percent of that of the United States in 1958, about 104 percent of the United States in 1961, and 115 percent in 1963.

Needless to say, these estimates might contain a sizable margin of error. Yet it does not seem probable that the errors could be as large as to change the broad conclusions; namely, that the Soviet industrial defense establishment has grown at the rate more than twice that of the Soviet economy; that by 1963 it was in absolute terms about as large or larger than that of the United States, despite the fact that the size of the Soviet economy was less than half of the United States; and that the growth of this establishment must have been a factor in poor efficiency performance of the economy at large.[120]

VII. The Prospects

MAJOR DEVELOPMENTS BETWEEN 1962 AND 1964–65

Due in part to time limitations and in part to preliminary nature of the available data for 1965, and even for some of the 1964 data, I can discuss the developments that took place between 1962 and 1965 in substantially less detail than the preceding parts. A brief analysis of the tentative data which seems feasible, however, will probably suffice to make a bridge between pre-1962 developments, the primary target of the investigation, and the developments anticipated for the not too distant future.

On the Soviet technological front the 3 years between 1962 and 1965 witnessed a variety of trends, but most of the changes point to an acceleration in the rate of overall technological change, and this not only in comparison with the 1940–62 period, but also in comparison with 1950–62. The speedup was most notable in the relative use of natural gas versus all other energy sources, which gained 3.7 percentage points between 1962 and 1963 alone or 1.85 percentage points per year (compared to not quite eight-tenths of 1 percentage point per year in the preceding 12 years); the rate of growth in output (and presumably use) of synthetic resins and plastics, which in the 3 years was almost double of the average rate in the preceding 12 years; a half percentage point gain in the relative use of metal-forming machine tools versus metal cutting, or more than in the preceding 8 years; and an almost double rate of growth in the use of commercial fertilizer in agriculture compared to the preceding 12-year average. The slowdowns were most pronounced in the relative use of oil compared to other energy sources, (the relative use of oil actually seems to have

[120] In the clandestine speech Aganbegian also made reference to the size of the Soviet defense establishment. The pertinent statement reads: "* * * We spend a great deal for defense and we have much difficulty in competing with the United States in this field because we must spend almost as much as they do while our economic potential is only about half theirs. Of about 100 million of the active population about 30 to 40 million work for defense." Cf. ASTE Bulletin, op. cit., p. 2. In the light of the estimates presented in the text, Aganbegian's comparison of the Soviet defense expenditures with the United States would seem to understate the Soviet expenditures rather than to exaggerate them. In this, however, we cannot be sure because the cost of the "hardware" is not the whole defense budget. I tried to figure out what he might have included in the 30 to 40 million people working for defense but did not get anywhere in the attempt.

slightly declined between 1962 and 1964 despite a relative increase in output), and a cessation of substitution of coal for "nonefficient" (wood, peat, shale, etc.) energy sources.[121]

The growth of prime inputs, GNP and productivity, however, did not follow the overall trend in technology. The Soviet total labor input grew in the 3 years at the average rate of about 2.1 percent per year,[122] or two-tenths of 1 percentage point faster than the average for the 1950–62 period; gross fixed business capital stock at the rate of about 10.2 percent per year,[123] or three-tenths of 1 percentage point less than the average for the 1950–62 period; and GNP, according to Stanley H. Cohn's preliminary estimate, at about 5.2 percent per year, or some 18 percent less than the average for 1950–62. This combination of the prime inputs and GNP growths implies (using 70–30 input weights) that in the 3 years the Soviet economy's aggregate factor productivity grew at the rate of about seven-tenths of 1 percent, or only about two-fifths of the average rate the economy had during the 1950–62 period.

In some measure this drastic deterioration of the Soviet economy's overall productivity growth, despite an acceleration in the rate of technological change, was due to adverse climatic conditions in agriculture in 1963. For the most part, however, it was apparently due to a further worsening of the utilization of the resources on hand. According to an authoritative recent source, the share of uninstalled equipment in the total equipment of the Soviet industry increased from 9.9 percent in 1960 to 12.5 percent in 1963.[124]

The information for a reasonably accurate evaluation of the pertinent developments between 1962 and 1965 in the United States will be available only about a year from the time of this writing. Based on what is currently available it appears, however, that the U.S. rate of technological change in these 3 years was about the same as the average for the 1950–62 period, but faster than in 1955–62; the growth of labor input (total civilian employment) averaged about 2 percent per year,[125] or almost twice as much as in 1950–62; gross fixed business capital stock averaged about 3.8 percent per year,[126] or almost 20 percent higher than the average for the 1950–62 period; and the growth of GNP averaged 4.8 percent per year,[127] about 40 percent higher than the average growth in 1950–62. This combination of the growth of the GNP and the prime inputs implies that the U.S. aggregate factor productivity growth averaged about 2.4 percent per year in these 3 years, some 40 percent higher than between 1950 and 1962 and about 3.4 times as high as the Soviet economy's rate was at the time. The absence of an acceleration in the rate of technological change compared to the earlier 12-year period also implies that all or

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[121] This brief outline of the trends in technology is based on data published in Narodnoe Khoziaistvo, 1964, and *S.S.S.R.* v. *Tsifrakh*, 1965.

[122] Based on Murray Feshbach's estimate of growth in employment presented elsewhere in this symposium.

[123] Cf. Narodnoe Khoziaistvo, 1964, pp. 68 and 258 and *S.S.S.R.* v. *Tsifrakh*, 1965, p. 27.

[124] Cf. L. Gatovskii, "Ekonomicheskaia nauka i nekotorye problemy tekhnicheskogo progressa" (Economics and Some Problems of Technical Progress), Voprosy Ekonomiki, No. 12, 1965, p. 9.

[125] Cf. The Economic Report of the President, 1966, table C–20, p. 232.

[126] This rate is derived from my own rough extrapolation of the Office of Business Economics estimates of gross fixed business capital stock from 1962 to 1965 based on investment data. It might be subject to some error, possibly as much as two- or three-tenths of 1 percentage point.

[127] Cf. Survey of Current Business, March 1966.

most of the increase in the rate of total factor productivity growth over the 1950–62 average must be attributed to the increase in the rate of the U.S. economy's capacity utilization from 1962 to 1965 rather than to technological change in a proper sense of the term.

The poor efficiency performance of the Soviet economy has worried numerous Soviet economists of the Aganbegian-type for a long time. The recent drastic deterioration, both in comparison with its own past and, particularly, in comparison with the United States most recent performance, however, has caused concern in Government circles as well. This official concern resulted in a wide-scale institutional reform, which was announced by Premier Kosygin in his speech to the Presidium of the Central Committee of the Communist Party of the U.S.S.R. on September 28, 1965.[128]

As stated by Kosygin, the objectives of the reform are: to increase the rate of technological progress, to reverse the downward trend in the growth of efficiency, and to assure the continuation of a high overall growth of the economy. These objectives are supposed to be accomplished by a vast program of institutional changes that might be summarized in the following eight points:

(1) Abolition of the regional (sovnarkhoz) system of industry management adopted in 1957 and the return to the system of commodity ("branch") line ministries similar to that which prevailed prior to the 1957 reform. This change should "correct negative results (of sovnarkhozy) in the sphere of technical progress, in the development of industrial production, specialization, and adequate production relations among individual enterprises."

(2) Granting greater autonomy to industrial plants and their associations (largely yet to be organized) with respect to their direct relations with other plants and associations, changes in their product-mix, and initiation of small investment projects, including greater freedom to borrow for such purposes.

(3) Gradual reduction in the number of commodities the production and distribution of which will be planned by the state planning agency (as the plants and the associations establish workable direct "business" contacts).

(4) Introduction of sales volumes, profits and profit indexes as additional indicators of performance of industrial plants. The addition of these indicators should raise the quality of products (which assumes that the plants producing low quality products will have to improve the quality in order to increase the sales to the level assigned to them in plans) and this, in turn, will increase the efficiency of the economy.

(5) Improvement in the system of material incentives for the working people conductive to "finding new reserves within enterprises and creating new means for raising wages of industrial and office workers."

(6) Introduction of charges for working and fixed capital used by enterprises. In the (unspecified) future these charges shall "become the most important part of the State's income." The obvious objective of this change, which represents a drastic "deviation" from longstanding dogmas, is to force enterprises to use capital assets more efficiently.

[128] See Pravda, Sept. 28, 1965. An English translation of the speech may be found in the Vital Speeches of the Day, Dec. 1, 1965, pp. 115–128.

(7) Sometime in 1967 or 1968 to revise wholesale and retail prices. The stated objective is that "prices must increasingly reflect expenditures of socially necessary labor, cover the production and turnover outlays and secure the profits of each normally functioning enterprise." The adjective "normally functioning" implies that the average rather than marginal costs will serve as criteria for the price setting.

(8) Although not officially announced, the recently concluded deal with the Fiat Co.,[129] the reported negotiation with the Renault Co.,[130] and Kosygin's expressed interest in arranging similar deals with Great Britain [131] strongly suggest that the reform included also a plan for tapping advanced foreign technology on a much wider scale than ever before and, especially noteworthy, to do this rapidly and in an apparently businesslike manner.

THE PROSPECTS

In an attempt to map out the future course of the principal variables of the Soviet economy under discussion in this study, more specifically from 1965 to 1970 or thereabout, we must obviously consider not only the recent trends, but also the apparent objective potentialities for future changes as well as the probable effects of the institutional reforms initiated at the very outset of the period under consideration.

Focusing on prospects for technological change, most factors point to a continuation of the most recent (1962–65) trend, and possibly a slight acceleration. The most important factors pointing to this probability are the room for profitable and relatively easily accomplished innovations, the regime's apparently serious determination to make greater use of the potentialities for technological change, and the prospective decline of the "built-in" environmental obstacles to such changes.

With respect to the "room for profitable innovations" we must note that in 1962 the Soviet economy's overall level of new technology use was some 20 to 25 years behind that of the United States. During the 1962–65 period, this overall lag was somewhat reduced but not much. Hence, the "room for improvements" in the next 5 years or so is still practically limitless.

Moreover, to achieve a somewhat faster rate of technological change than in the past no essentially new "know-how" will be needed and no shortages of skilled manpower can be expected. As has been noted earlier, by 1962 the Soviet economy had used at least on a token basis virtually all innovations that were used in the United States at that time. As at the present time, skilled manpower will actually be in excess supply for some time to come. Whatever new or better "know-how" will be needed, the management will apparently be able to import it from abroad, at least to the extent the economy will be able to pay. In this, however, the possibilities of large expansion of oil output on one hand and rigid control of domestic oil consumption, on the other, will probably provide the management with a fair amount of flexibility.[132]

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[129] The Journal of Commerce, May 19 and 31, 1966.
[130] Ibid., May 24, 1966.
[131] Ibid., June 9, 1966.
[132] Between 1958 and 1964, the Soviet output of oil grew at the rate of about 8.9 percent per year, but net exports at 17.6 percent, or twice as fast as output. The net exports constituted 12.8 percent of the output in 1958, 23.9 percent in 1962, and 28 percent in 1964. For the ratios of net export to output in earlier years see note 73 above.

Also, at least in a technical sense, the "new" commodity-line management of industry is likely to prove somewhat more conducive to technological change than was the sovnarkhoz system.

The prospects with respect to overall productivity growth, however, are not so clear as this growth will depend not only on the rate of technological change but also on how rapidly management succeeds in reversing the recent downward trend (or in closing the divergence between the rate of technological change and productivity growth) and this, in turn, will depend on how far and how rapidly the regime will go in "rationalizing" the system. It is conceivable that for some time things might get worse before they get better. The odds seem to be fairly high, however, that the downward trend will be reversed in a year or two, barring obviously excessively adverse climatic conditions; then the growth in productivity will parallel the rate of technological change. This should result in a 5-year average rate fairly close to 1.7 or 1.8 percent, or what the Soviet economy averaged in the 1950–62 period.

In projecting this overall productivity performance I assume, first of all, that in those 5 years the Soviet management will not undertake such far-reaching "voluntaristic" decisions as was Stalin's energy policy, but semiarbitrary (or at least "suboptimal") decisions will be commonplace throughout the period despite the reform. The primary reason for this is that the present price system does not permit rational decisions, and the probability is that the new prices, which realistically can become available only toward the end of the 5-year period, will not be much better.[133]

Judging by Kosygin's remarks in speech announcing reform, the management is aware of the efficiency inhibiting disproportionalities in the Soviet economy in general, and in the supply of capital goods in particular (especially disproportionalities in the supply of auxiliary equipment versus direct production equipment). One might presume that a serious effort will be made to correct these deficiencies. Considering how long the "mastering" of new production takes in the U.S.S.R., however, this correction will probably take considerably longer than the 5 years we are concerned with here.[134]

The reform provision for direct contacts between enterprises, sales quotas and profit indexes will undoubtedly tend to improve the present system of production and distribution of goods, particularly capital goods, as well as raise the quality of the goods, but the process of improvement will be very slow and check the growth in productivity of the industry (the way we measure it, of course).

The primary reason for this is an apparently considerable heterogeneity of Soviet industrial enterprises with respect to quality of products they produce. Judging by the references in the Soviet press, a large proportion of all enterprises produce consumer products that

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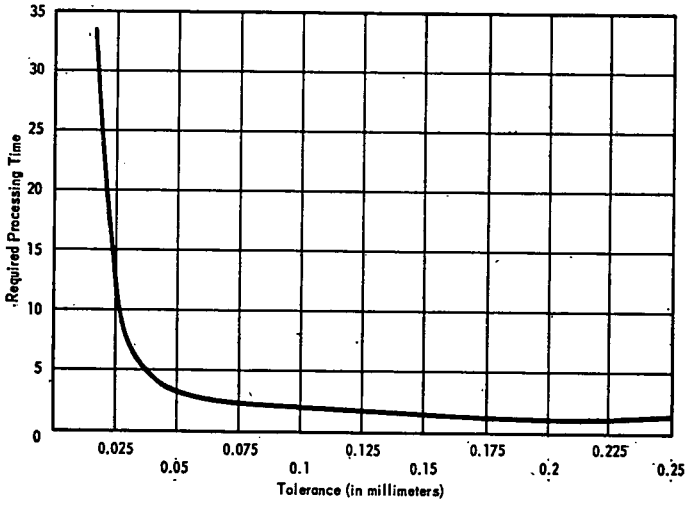
[133] In addition that they will be tailored to the industries' average rather than marginal costs, in many instances they will probably deviate materially even from average cost. L. Gatovskii, who might be presumed to know about what is coming as much as anyone in the U.S.S.R., states: "The prices of new products should * * * be set in such a way that it will be advantageous to use new technology not only for producers but also for users." Cf. Voprosy Ekonomiki, No. 12, 1965, pp. 16–17.

[134] Judging by the growth rates of metal-cutting machine tools, which constitute probably the best example of direct production equipment, the process of correction would seem to have started in 1964. Between 1950 and 1963 the output of metal-cutting machine tools grew at an average rate of 7.6 percent per year. Between 1963 and 1964, however, this output increased only by six-tenths of 1 percent and between 1964 and 1965 by one-half of 1 percent. Cf. Narodnoe Khoziastvo, 1964, p. 183, and *S.S.S.R.* v. *Tsifrakh*, 1965, p. 58.

nobody wants to buy. The magnitude of the industrial equipment repair problem, outlined in the preceding part, points to an analogous situation in the area of capital goods production. In order to make use of the provisions of "direct contacts" the sales organizations and large direct users of capital goods will undoubtedly make "a run" on manufacturers producing reputable products. The capacity of the reputable enterprises, however, will hardly suffice to satisfy the demand. The second-rate enterprises might get by unharmed, but the enterprises manufacturing poor or unacceptable products will be put under pressure to improve the quality. This could hardly be done without increase in cost and/or reduction of quantities produced. In many instances this will not only prevent the productivity from growing, but actually cause a substantial decline.

For an illustration as to what this might mean to enterprises manufacturing poor machinery I refer to figure 1 which, in the source's terms, describes the "general law of the interdependence between the

Functional Relationship Between Accuracy in Manufacture of Machinery Parts (Quality) And Time Required for Their Manufacture



cost of manufacture and the accuracy of manufacture." [135] The graph is derived from an observed relationship (under static technology) between the quality of machinery parts, measured by various tolerances, and the time required to achieve these tolerances. Prevailing tolerance of machined parts is obviously only one of many indicators of the quality of a machine, but it is probably the most important and is fairly representative of the cost-quality relationship of other indicators as well (such as quality of materials, quality of design, etc.). Poor tolerances of machine parts usually mean high vibrations and friction of joints, and this is the most frequent cause of breakdowns.

[135] The figures is reproduced from S. A. Kartavov, Osnovy ratsionalnogo proektirovaniia mashin (The Foundations of Rational Design of Machinery), Kiev, 1954, p. 170.

The U.S. manufacturing engineers whom I consulted on the point tell me that if a machine has a high incidence of breakdowns (and, hence, requires frequent repairs) it is probable that the tolerances of its machined parts do not exceed ±0.2 millimeters (±eight one-thousandths of an inch). In order to reduce the incidence of breakdowns to reasonable frequency, the machining tolerances would have to be reduced to ±0.125 millimeters (±five one-thousandths of an inch). As shown in the graph the reduction of the tolerances from ±0.2 millimeters to ±0.125 millimeters would require an increase in the manufacturing time factor from about 1.5 to about 3, or roughly 100 percent.[136] The volume of machinery repair work in the Soviet economy suggests that in the drive for quality perhaps as many as half of all Soviet machinery factories might face such a situation.

It is obviously impossible to draw firm generalizations from this information. But, in conjunction with the volume of the Soviet economy's capital equipment repair work outlined earlier, it strongly suggests that the problem of the quality of products is much more serious than we have been accustomed to believe and that this problem probably cannot be solved without substantial loss of "productivity growth" and time, and this not only in the area of machinery production but also in the economy at large.

The imposition of explicit charges for the use of capital assets upon enterprises is long overdue and will undoubtedly be conducive to a more efficient use of capital assets. With the product prices to be geared to average rather than marginal costs, however, the measure will not be as effective as it would be with prices geared to marginal prices. In addition, even in situations where it will prove effective it will probably take some time before the results will become noticeable.

The promises for improving "Lenin's principle of material incentives" are obviously as old as the Soviet system. At the present time, the appropriations (or, rather, "cost deductions") for "development" funds in the enterprises from which the incentives premia are to be paid are made entirely arbitrarily. The changes that are supposedly to be made in the not too distant future will probably constitute little substantive improvement compared with the past, and the improvement, as in the past, is likely to be double edged.[137] On the whole, however, the disbursements for purposes of motivational improvements will be greater than in the past, and this should benefit productivity in the long run.

The role of the industrial defense establishment for the productivity growth in this period cannot obviously be predicted. However, there is little reason to believe that it could materially change in the 5 years to come compared with the most recent past.

The preceding considerations imply that the share of national income going to labor is likely to increase somewhat. Other things being equal this should work toward a smaller rate of fixed business

[136] I should note that the tolerances of ±0.125 millimeters (±five one-thousandths of 1 inch) are by no means extraordinary. In fact, my engineering consultants tell me that such machining tolerances were prevailing in the United States and the advanced West European countries some 15 to 25 years ago. By now, the prevailing practice is said to have advanced to around ±0.025 millimeters (±one one-thousandth of 1 inch) and the "precision work" by now commonly begins with tolerance of ±0.0125 millimeters (±five ten-thousandths of 1 inch).

[137] E.g., the "Stakhanovite" piecework incentives which pushed quantity production at the expense of quality and current premia for overfulfillment of plans for quantity output which, too, work against the quality of products.

capital formation than was the case in the past. In addition to a smaller rate of investment, the probability is that the rate of fixed business capital formation in the next 5 years will also be adversely affected by increasing rates of old capital retirement due to official "disenchantment" with perpetuation of obsolete capital stock by means of costly repair [138] and an apparent large over-capacity for production of certain new capital goods, notably machine tools. On the whole, it seems probable that the gross fixed business capital stock will grow at the rate of some 7 or 8 percent per year, or about a third less than in the preceding 15 years.

The growth of labor input in the 5-year period, finally, might obviously be considered as almost a datum. According to Murray Feshbach's calculation, the Soviet civilian employment is most likely to increase by 1970 to about 119.5 million, from 106.4 million in 1965, which implies an average growth rate of about 2.3 percent per year.

The above separate projections of Soviet growth of labor input, fixed business capital stock and aggregate factor productivity represent obviously all the ingredients that are needed for determination of the Soviet economy's prospective growth of GNP for the 1965–70 period. This and its components are likely to be roughly as follows:

	Percentage points
Labor contribution (2.3×0.72)	1.7
Fixed business capital stock (7 to 8 percent × 0.28)	2.0–2.2
Aggregate factor productivity	1.7
GNP growth (per year)	5.4–5.6

Compared to the U.S.S.R., the projections for the United States are both more difficult and easier. The difficulty stems from the lack of an as instructive reference with respect to potentialities for technological progress as the U.S. technological history provides for the U.S.S.R. The easier side, in turn, is due to the fact that the U.S. economy, by now, does not seem to be subject to as large uncertainties in performance as the Soviet economy is.

On the technological front the best that the U.S. economy can expect is a continuation of change at the rate that has prevailed since 1950. Moreover, most of the progress will center around computers (automatic data processing and industrial process control); expansion in the use of synthetic fibers, resins, and plastics; numerically controlled machine tools; oxygen steel process, insecticides, etc., that is, the same innovations that have constituted the principal levers of change in the last 10 years or so. The first half of the 1960's does not seem to have produced a thing that could acquire economywide significance in the second half of the decade or even thereabout.[139] Nor do there seem to be bright prospects for imports of new foreign technology that could change this trend.

Because the rate of capacity utilization, the other major factor assumed to affect the aggregate factor productivity growth, cannot be expected to increase much beyond the level achieved in 1965, the

[138] Cf., Gatovskii, op. cit., pp. 11–12; and P. Bunich, "Ekonomicheskoe stimulirovanie povyshenia effektivnosti kapitalnykh vlozhenii i fondootdachi" (Economic Stimulation of Effectiveness of Capital Investment and Capital Productivity), Voprosy Ekonomiki, No. 12, pp. 21–34.

[139] "Laser" is a good candidate for a big thing, but its effects are unlikely to be noticeable until 1970's.

total factor productivity is likely to grow at only the rate that prevailed between 1950 and 1962, that is, about 1.7 percent per year.

Due to the expected continuation of the present governmental "high demand" policies, however, the rate of growth of gross fixed business capital stock will probably average about 4 percent per year, some 25 percent higher than in 1950–62 and even slightly higher than in 1962–65.

The same governmental policies will also probably keep the unemployment rate at 4 percent or less and thus assure the growth of labor input at a rate of about 1.9 to 2 percent per year.

With such growth of prime inputs and the aggregate growth of productivity by about 1.7 percent per year, the U.S. (real) growth of GNP should average some 4 percent per year in the second half of the 1960's.

The projected comparative growth rates imply that the output (GNP) of the Soviet economy will increase by 1970 to about 51 percent of the United States which will represent a relative gain of 3.5 percentage points in the 5-year period, the Soviet economy will also succeed in reducing a little its technological gap, but its relative gap in overall productivity will remain the same as it was in 1950, and even slightly larger than in 1940.

APPENDIX A

SOVIET VIEWS ON ECONOMIC EFFECTS OF TECHNOLOGICAL CHANGE

As noted in the discussion of approaches currently used in studies of technological change, most Soviet analyses of technological change are case studies or attempts at various types of generalizations based on case studies. The leitmotiv in these studies is either what technological change does to the Soviet or, even more, to the U.S. economy, or what it can and supposedly will do to the Soviet economy, and this mostly in terms of cost saving, growth in productivity, savings of capital, and the like.

Undoubtedly, much of what is being written about technological change in Soviet literature is sheer propaganda, but much also seems to be valuable and is of great interest to students of technological change not only in the U.S.S.R. but also in the West and, perhaps, in the underdeveloped countries.

I have summarized much of the information on the economic effectiveness of various technological changes that appeared to me to be valuable or unique, and this summary is presented in table A–1.

With respect to the data presented in table A–1 two points have to be noted.

First, one must obviously bear in mind that these data, as any other Soviet cost data, contain inaccuracies by Western standards on account of the absence of interest and rent charges and various other deficiencies of Soviet cost accounting practices.

Second, the data on the effectiveness of increased mechanization and automation in industry are based on two special sample surveys conducted by the Central Statistical Administration in 1959 and 1960. These surveys covered a total of 7,937 investment projects involving increases in mechanization or introduction of automation, carried out in 1,357 plants in 1958 and 1959 in 8 different sectors of industry at a cost of 845 million rubles (in the respective years' currency denomina-

tion) or about 106,000 rubles per investment project. To my knowledge such broad case study of mechanization and automation has never been done anywhere else and, therefore, the information is unique. The data on all other innovations listed in the table, as far as we can judge, are either estimates prepared by the technological projectmaking institutes, the studies of which are usually based on experience in laboratories or experimental plants; engineering calculations; or some other special investigations. Therefore, they must be viewed as very rough approximations of potentialities rather than as accurate, actual measures in any sense of the term.

Apart from the wealth of specific information summarized in table A–1, the broad view of the economic significance of technological change, which almost all Soviet writers on technological change appear to hold, should also be of interest.

Currently, to most Soviet writers technological progress means a reduction of total cost to the economy resulting from the application of specific technological innovations. This, however, has not always been so. Some 10 years ago they considered technological change to mean only a reduction in unit labor requirements. Now they speak in terms of total cost. The savings in total cost resulting from technological change are attributed to savings in the cost of labor; savings in cost of capital; and, always in prominence, savings in cost of materials. Most generalists seem to believe also that savings in the cost of labor are by far more substantial than savings in the cost of capital, and savings in the cost of capital more substantial than savings in the cost of materials.

Most Soviet writers comment on reduction of the cost of labor and labor productivity increases as if they were the same thing. Some, however, seem to distinguish between the two. The reason for the difference, of course, is that in most innovations the total skill requirement declines less than the total labor requirement. Unfortunately, these writers furnish very little information amplifying this exceedingly interesting proposition. Of what is available the most revealing seems to be the information bearing on the impact of automation (narrowly defined) in metalworking summarized in table 2. As is shown in the table, automation reduces the total production labor requirement by some two-thirds but increases the skill requirement of the average production worker by about 40 percent. The result of this is that the total skill requirement decreases only by 54 percent, or about 13 percentage points less than the total labor requirement. What this argument really amounts to is that automation presupposes more skilled manpower than the conventional methods of production, but the aggregate skills of the workers displaced are proportionately greater than the increase in skills required to tend the automation. Hence, the implication is that automation brings increasing returns to skills.

With respect to the impact of technological change on capital cost the general view seems to be that there is a very strong tendency for technological change to result in reduced unit capital cost. The exceptions are very rare. Of the 30 innovations listed in table A–1, only long-distance transmission of electricity instead of the transportation of coal over the distance (assuming obviously availability of railroad tracks) involves in some cases, though not in all, some increase in unit capital cost.

The principal reason that technological change generally tends to reduce unit capital costs seems to be viewed as a matter of expediency. In order for a technological innovation to gain wide use in the economy, the economic advantages of this innovation must be substantially greater than its cost.

The magnitude of the capital cost savings of an innovation is thought to depend largely on whether the innovation represents a drastic departure from a conventional method or constitutes merely extension of this method. Generally, the greater the deviation from conventional method, the greater the reduction in unit capital cost is likely to be.

An illustration of this proposition is provided in table A–2. The table lists four types of machine tools capable of performing metal turning operations along with the approximate indexes of their productivity and the costs relative to a standard engine lathe, the most commonly used equipment for that purpose. It will be noted that the growth in the cost index lags progressively behind the growth in productivity and that the disparity between the two indexes grows from 1/1 to 5/1 (2,200/400). The greatest disparity is between the engine lathe and the 8-spindle automatic lathe; the latter represents the most radical departure from the practice commonly used.

In cases where technological change is in the form of a mere extension of conventional technology the disparity between such indexes is likely to be much smaller. Sometimes the indexes may even approach certain regularity along the "Konson's formula." [1] According to this formula, observed initially in cases where technological progress took place in the form of increased sizes of electrical machinery, the cost increases to the 3/4 power with the increase of the equipment size or the increase in productivity. Needless to say, this generalization should be interpreted as a convenient engineering "rule of thumb" rather than in any sense a precise relationship.

It will be noted that Konson's rough generalization is not unique and has American counterparts. Similar American "rules of thumb" were debated in economic literature about 6 or 7 years ago.[2]

The exceptions to the general tendency of technological progress to reduce unit capital costs are said to arise in situations where technological changes are necessitated by a physical impossibility of carrying on production with previous techniques because of natural conditions (for example, the need to drill deeper for oil, which requires more or newer and better equipment), or a necessity to substitute capital for labor in short supply without increasing output.

The savings of materials as a result of technological change vary immensely from industry to industry and innovation to innovation. The material-saving innovations to which references are made most frequently are the generation of electric energy by means of a 600-megawatt turbogenerator, which requires some 2 or 3 percent less fuel per unit of output than the generation by a 100-megawatt unit; the manufacture of the generating equipment per kilowatt of capacity in

[1] See A. S. Konson, "Ekononicheskaia effektivnost' novoi tekhniki" (Economic Effectiveness of Technical Innovations), Gospolitizdat, Moscow, 1958, pp. 154–160 and the comment on the proposition from a different point of view in my earlier study, The Soviet Challenge to U.S. Machine Building, p. 21, and app. C, tables 1 and 2, pp. 55–60.

[2] See Frederick T. Moore, "Economics of Scale: Some Statistical Evidence," in Quarterly Journal of Economics, vol. LXXIII (May 1959), pp. 232–245, and Alan A. Walters, "Economics of Scale; Some Statistical Evidence: Comment," ibid., vol. LXXIV (February 1960), pp. 154–157.

600-megawatt units which requires some 40 percent less metal than the manufacture of 100-megawatt units; the use of plastics, each ton of which "saves" several tons of ferrous and nonferrous metals; the production of various chemicals from natural gas or oils, which results in enormous savings of organic materials; the use of the oxygen converter process in steelmaking, which saves large quantities of fuel and electric energy; and other similar innovations.

Of the other effects of technological change, frequent mention is also made of the decrease or elimination of physically strenuous work, improved hygienic conditions of work, differential impact of new technology upon capitalist and Communist societies, and the like, but most of the discussions of these effects are either heavily propagandistic or superficial.

TABLE A–1.—*A synopsis of 30 major technological innovations in process of introduction and/or diffusion in the Soviet economy and their alleged economic effectiveness*

[In percent]

Innovation	Effects			
	Savings in total cost per unit of output	Increase in productivity of labor	Saving in total capital cost per unit of output	Next year return on the investment in the innovation
1. Substitution of oil for coal as energy source for use in the economy	60–70	300–400	50–60	15–20
2. Substitution of natural gas for coal as energy source for use in the economy	80–95	1,200–1,300	70–80	55–65
3. Increased mechanization [1] in agriculture	(2)	50–150	(2)	(2)
4. Increased mechanization and automation [1] in industry	2–30	10–500	10–20	30–300
(a) Mechanization of manually performed technological processes	(2)	(2)	(2)	70–300
(b) Mechanization of material handling and storage operations	(2)	(2)	(2)	30–280
(c) Automation of technological processes by use of new nonintegrated automatic and semiautomatic equipment in place of old nonautomatic equipment	(2)	(2)	(2)	50–300
(d) Automation by means of additions of new new automatic devices to existing nonautomatic equipment	(2)	(2)	(2)	40–150
(e) Automation by means of addition of integrating automatic control systems to separately working automatic equipment units	10–30	300–500	10–20	35–220
5. Use of automotive transport for short haul freight traffic and intraplant transport instead of railroads	40–60	100–200	(2)	80–85
6. Strip (surface) mining of coal and ores instead of underground mining	75–80	300–600	25–50	25–50
7. Hydraulic mining of coal	25–30	50–250	(2)	(2)
8. Oil well drilling by means of diamond gouges (chisels) instead of steel	20–25	30–40	10	(2)
9. Use of large (820 millimeter) diameter pipelines instead of small (529 millimeter) diameters in transportation of oil and gas	(2)	100	50	(2)
10. Production of electric power by means of steam turbogenerators with unit capacity of 600,000 kilowatts instead of 100,000 kilowatts	30	50	40	(2)
11. Production of electric energy by means of gas turbines instead of steam turbines (up to 100,000 kilowatts unit capacity)	(2)	(2)	20–25	(2)
12. Long-distance transmission of electricity by means of extra high voltage (EHV) lines instead of transporting coal over the distance	10–40	(2)	(2)	8–50
13. Production of pig iron in 2,000 cubic meter blast furnaces instead of furnaces half that size	20	80	25	(2)
14. Production of steel in open hearths with 500-ton unit capacity instead of furnaces half that size	9	11	20	(2)
15. Use of oxygen in production of pig iron in blast furnaces	5–10	25	15	(2)
16. Use of oxygen in production of steel in open hearth furnaces	5–10	25	15	(2)

See footnotes at end of table.

TABLE A–1.—*A synopsis of 30 major technological innovations in process of introduction and/or diffusion in the Soviet economy and their alleged economic effectiveness*—Continued

[In percent]

Innovation	Effects			
	Savings in total cost per unit of output	Increase in productivity of labor	Saving in total capital cost per unit of output	Next year return on the investment in the innovation
17. Production of steel by means of basic oxygen converter process instead of open hearth process	5–10	20–25	15–20	(3)
18. Use of continuous casting process in production of steel	10–12	(2)	40–60	(2)
19. Substitution of metal-forming processes for metal cutting (machining) in metalworking industries	20–30	100–200	(2)	(2)
20. Use of numerical (tape) controlled machine tools in "batch-type" metalworking production	25–30	75–125	40	(2)
21. Manufacture of cement in plants having continuous production cycle instead of "batch" (discrete) production	70–75	900	75	(2)
22. Use of synthetic instead of natural cord in automobile tire production	15	(2)	25	(2)
23. Use of synthetic fibers instead of cotton, wool, or silk in production of textiles	67–75	300–400	30–60	(2)
24. Application of synthetic materials (plastics) for cable and pipe insulation	45	(2)	80	(2)
25. Use of synthetic (plastic) materials instead of steel or nonferrous metals in production of parts for appliances and machinery	75–85	100–900	55–70	30–40
26. Joint production of various chemical products from natural gas instead of independent production of these products from other raw materials	50–67	1,000–1,300	30–50	(2)
27. Control of industrial plants with continuous flow of production by means of computers instead of conventional types of instrumentation	50–67	1,000–1,200	30–50	(2)
28. Use of electronic data processing equipment in planning and administration of industry	(2)	(2)	(2)	50–67
29. Optimization of designs of railroad tracks by means of computer programing of cost of tracks	10	(2)	(2)	(2)
30. Application of mineral fertilizers in agriculture	15–20	50–67	(2)	50–150

[1] Mechanization is generally defined as introduction of non-automatic tools or machinery to replace manual or innovate mechanized operations; and automation as introduction of devices and equipment making two or more mechanized operations automatic.

[2] Not available.

[3] From plus 10 to minus 15 percent.

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TABLE A–2.—*Approximate impact of automation on total production labor and production labor skill requirements in Soviet metalworking production*

Indicator	Nonautomated (mechanized) production	Automated production
Total man-years required for comparable output, number	1,000	333
Man-years required by skill classes, number class:		
3	432	11
4	343	93
5	188	105
6	30	55
7	7	47
8		22
Average skill class	3.8	5.4
Total skill requirement in skill class units (total man-years multiplied by average skill class)	3,837	1,764

Source: Derived from data on percentage distribution of production labor in nonautomated (mechanized) and automated metalworking production as given in I. Ia. Miasnikov "Automatizatsiia i Kommunizm" (Automation and Communism), Ekonomika, Moscow, 1964, p. 76, and an assumption, consistent with data in table A–1 that automated production increases overall productivity of labor by about 300 percent.

TABLE A–3.—*Approximate relationship between changes in equipment productivity and its manufacturing cost in the field of machine tools*

Type of machine tool performing comparable function	Approximate index of equipment productivity (percent)	Approximate cost (price) index of equipment (percent)	Ratio of cost (price) index to productivity index
Universal engine lathe	100	100	1.00
Universal turret lathe	160	140	.87
1-spindle automatic lathe	880	220	.25
4-spindle automatic lathe	2,200	440	.20

Source: Derived from data on relative productivity of the machine tools as given by G. A. Shaumian, "Avtomatizatsiia proizvodstvennykh protesessov v mashinostroenii" (Automation of Production Processes in Machine-Building), Trudrezervizdat, 1958, p. 19, and price data on machine tools given in "Materialy i oborudovaniie primeniaemye v ugolnoi promyshlennosti, Spravochnik" (Materials and Equipment Used in Coal Mining, Handbook), Vol. 11, part 2, Ugletekhizdat, 1957, pp. 274–345).

APPENDIX B

Estimates underlying the weights used in aggregation of individual indicators of technological change (text table 1) into the overall rate of Soviet technological change relative to the United States (text table 3)

Item No.	Indicator	Measure of unit change in the indicator	Potential saving of man-years per unit change in the indicator in the U.S.S.R. in 1959	Percent of the total (weight)	Legend
1	Increase in the share of natural gas in the total of all fuels consumed by the economy.	Percentage point	14,280	6.0	Saving of about 76 man-years to the economy for each trillion of B.t.u. in gas substituted for coal (36,000 bituminous metric tons).
2	Increase in the share of oil in the total of all fuels consumed by the economy.	do	9,520	4.0	Saving of about 54 man-years to the economy for each trillion of B.t.u. in oil substituted for coal.
3	Decrease in the share of fuel wood, peat, shale, and other inefficient in the fuel total consumed by the economy.	do	7,140	3.0	Saving of about 41 man-years to the economy for each trillion B.t.u. in coal substituted for inefficient fuels.
4	Increase in electric energy input per production worker in industry.	Percent	38,080	16.0	1 man-year saving per every 23,500 kilowatt-hours consumed above the preceding period's average per worker.
5	Increase in use of mechanical power per production worker in industry.	do	21,420	9.0	Saving of about ¼ of man-year per each mechanical horsepower added per worker.
6	Improvements in generation and transmission of electric power.	do	714	.3	Composite change.
7	Increase in the share of oxygen process in steelmaking	Percentage point	1,667	.7	Saving of about 1 man-year for every 500 tons of steel produced.
8	Increase in the share of aluminum in total consumption of basic metals.	do	3,332	1.4	Saving of about 1 man-year for about 75 tons of aluminum (about 220 steel equivalent tons) consumed.
9	Increase in the share of metal forming machines in total machine tool stock.	do	4,760	2.0	Saving of about 1.3 man-years per each metal forming machine substituted for metal cutting.
10	Increased use of N/C and other automatic metal cutting machine tools.	Percent	3,570	1.5	Composite, assumed about ⅜ of man-year saved for each machine added.
11	Increased use of synthetic resins and plastics	do	1,666	.7	Saving of about 1 man-year for every 10 tons used in the economy.
12	Increased use of manmade fibers	do	1,666	.7	Saving of about 1 man-year for every 1.3 tons used in the economy.
13	Increase in the share of automobile freight in the total freight traffic.	Percentage point	6,425	2.7	Saving of 1 man-year for every 200,000 ton-miles.
14	Increased share of pipelines in total freight traffic	do	15,470	6.5	Saving of man-year for about every 80,000 ton-miles.
15	Increased use of automatic data processing equipment	Percent	22,610	9.5	Saving of about 500 man-years for every new installation.
16	Increased use of tractors, combines, and trucks per acre of cropland in agriculture.	do	42,840	18.0	1 unit of the equipment added saves about ⅜ of man-year.
17	Increased use of 100 percent nutrient fertilizer per acre of cropland.	do	42,840	18.0	1 ton added above preceding period's average equivalent to saving of ⅜ of man-year.
	Total		238,000	100.0	

Sources: Estimated on the basis of (a) data on productivity increases resulting from various innovations summarized in app. A, table 1, and in "The Soviet Challenge to U.S. Machine Building," op. cit., app. D, pp. 62-68; and (b) employment data in respective segments of the Soviet economy compiled in "Annual Economic Indicators for the U.S.S.R., 1964," op. cit., table V-A-6, pp. 53-55, and Vladimir G. Treml, "The 1959 Soviet Intersectoral Flow Table," vols. I and II, Research Analysis Corporation Technical Paper RAC-TP-137, November 1964, table 32, pp. 95-96 (vol. I), and app. D, pp. 73-87 (vol. II).

APPENDIX C

Data underlying the factor productivity analysis set forth in part IV

Country and data	Measure	1940	1950	1955	1962
U.S.S.R.:					
(0) Gross national product (GNP)	Billion rubles in 1955 prices	74.7	92.6	128.6	192.0
(1) Civilian employment, unadjusted for changes in quality, sex composition, or hours worked.	Thousands	79,019	79,593	84,476	99,395
(2) Fixed business capital (gross), reproduction value	Billion rubles in 1955 prices	49.9	63.3	119.4	209.3
(3) Apparent consumption of mineral fuels and fuel wood	Trillion B.t.u	6,647	8,887	13,284	19,586
(4) Apparent consumption of basic metals (steel ingot equivalent)	Thousand short tons	20,913	(1)	48,034	82,894
(5) Total freight transportation	Billion ton-miles	334.7	488.6	798.0	1,450.0
(5a) Nonautomotive freight transportation (assumed to be intercity)	Billion ton-miles	328.7	474.9	768.5	1,373.2
(6) Consumption of electric energy	Billion kilowatt-hours	48.3	91.2	170.2	369.1
United States:					
(0) Gross national product (GNP), actual	Billion dollars in 1954 prices	203.6	318.3	392.4	474.9
(0a) Gross national product (GNP), potential	do	238.4	336.1	410.5	503.1
(1) Civilian employment, unadjusted for changes in quality, sex composition, or hours worked.	Thousands	47,520	59,987	63,196	67,999
(0a) Potential civilian employment (labor force)	do	55,644	63,344	66,105	72,033
(2) Fixed business capital stock (gross):					
(a) Assuming service lives of capital assets as postulated in Bulletin F	Billion dollars in 1954 prices	378.2	438.9	528.3	637.7
(b) Assuming service lives of capital assets 20 percent longer than postulated in Bulletin F.	do	446.4	521.8	610.1	739.1
(3) Apparent consumption of mineral fuels and fuel wood	Trillion B.t.u	23,488	33,536	39,301	46,856
(4) Apparent consumption of basic metals (steel ingot equivalent)	Thousand short tons	51,782	88,189	110,000	111,267
(5) Intercity freight transportation	Billion ton-miles	624.4	1,076.4	1,391.2	1,409.6
(6) Consumption of electric energy	Billion kilowatt-hours	181.7	396.3	637.3	951.0

[1] Not applicable.

SOURCES

U.S.S.R.: GNP adapted from A. Bergson, The Real National Income of Soviet Russia Since 1928, Harvard University Press, Cambridge, 1961; M. Bornstein "A Comparison of Soviet and the U.S. National Product," Comparisons of the United States and Soviet Economies, Joint Economic Committee, Congress of the United States, part II, Washington, 1959; and S. Cohn, "The Gross National Product in the Soviet Union; Comparative Growth Rates" in Joint Economic Committee's of U.S. Congress Dimensions of Soviet Economic Power, Washington, 1962, and Annual Economic Indicators for the U.S.S.R., Washington, 1964.

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Fixed business capital stock (gross)—is assumed to be equal to the Soviet concept of gross production capital (proizvodstvennye osnovnye fondy) in the economy net of the value of "working and productive" livestock. The concept excludes so-called "nonproductive" capital; that is, residential structures, structures and equipment used by government, municipalities, including such services as public laundries, banks, insurance agencies, party and trade union organizations and institutions of public health, education, arts, and other similar organizations. Estimates in the table are based on Narodnoe Khoziaistvo for 1960 and 1963 average annual indexes for all production capital; actual value of production capital as of Jan. 1, 1960, and Jan. 1, 1964; indexes of production capital inclusive and exclusive of "working and productive" livestock, the percentage realtionship of the value of the livestock to the total and an assumption that all Soviet capital livestock is concentrated in agriculture.

Apparent consumption of mineral fuels and fuel wood—Narodnoe Khoziaistvo for 1960 and 1963 and Vnieshnaia Torgovlia SSSR, editions for 1913–40, 1956, 1959, and 1963. The Soviet data given in kilocalories have been converted into B.t.u. by means of a ratio of 0.2520 B.t.u. per kilocalorie.

Apparent consumption of basic metals steel ingot equivalent tonnage (measure of volume of consumption) estimated on one basis of the same sources as mineral fuels. Data on consumption of shape metals were converted into ingot equivalents by means of a coefficient 1.429 which assumes a 70-percent yield of shaped metal per ton of ingot. The basic metals embrace, as in the analysis of technological progress, steel, aluminum, magnesium, zinc, copper and lead. The tonnage of non-ferrous metals was converted into steel equivalents by means of coefficients expressing average weight relationship of 1 cubic inch of steel to the respective metals.

Consumption of electric energy-Narodnoe Khoziaistvo, 1960 and 1963, data on total output of electric energy and an assumption of zero export or import.

United States: GNP, actual—U.S. Department of Commerce, Office of Business Economics, revised data as reported in Survey of Current Business, August, 1965.

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Apparent consumption of mineral fuels and fuel wood—U.S. Department of the Interior, Bureau of Mines, and Sam H. Schurr, et al., Energy in the American Economy 1850–1975, The Johns Hopkins Press, Baltimore, 1960.

Apparent consumption of basic metal—Estimates, analogous to those for the U.S.S.R., based on American Iron and Steel Institute, annual reports; U.S. Bureau of Mines, Minerals Year Books and U.S. Bureau of the Census (exports and imports.)

Freight transportation-Interstate Commerce Commission as reported annually in Statistical Abstract of the United States.

Consumption of electric energy—Data of the Federal Power Commission as reported in Statistical Abstract of the United States.

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THE 1959 SOVIET INPUT-OUTPUT TABLE

(As Reconstructed)

BY

Vladimir G. Treml

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THE 1959 SOVIET INPUT-OUTPUT TABLE

(AS RECONSTRUCTED)

INTRODUCTION

The three main statistical tables and the accompanying notes in this paper represent an extension of the study of the 1959 Soviet input-output table published earlier under the auspices of the Joint Economic Committee of Congress.[1]

In the last 10 to 15 years input-output analysis has come to be generally accepted as a highly useful and versatile tool of analysis of national and regional economic data.[2] Most Western countries have prepared, or are in the process of preparing, one or more input-output tables for their economies.

After some initial reluctance to use an analytical tool developed and perfected by "decadent bourgeois science," economists, statisticians, and planners in the U.S.S.R. and other countries of the Soviet bloc are also finding more and more use for input-output analysis. However, complete integration of input-output techniques with more traditional tools of central economic planning has not yet occurred. Most countries of the bloc have by now prepared one or several input-output tables of varying degrees of detail and statistical sophistication, and interest in the exploration of input-output techniques continues unabated. In the U.S.S.R. alone, to date a total of 10 national input-output tables have been completed or are in preparation, ranging from an 83-industry table in value terms for 1959 to a mammoth 600-product table in physical units being prepared for 1970, the terminal year of the current 5-year plan. Some 20 regional or interregional tables have also been prepared.

Needless to say, an input-output table is not only useful to government agencies of the country in question but is also of singularly great interest to an outside analyst. This is especially true when dealing with a country like the U.S.S.R. where, all the recent improvements in the flow of published statistics notwithstanding, our knowledge of economic data is severely limited. It must be emphasized that an input-output table need not necessarily be used as a whole entity for the study of overall national capacity, industrial interrelations, or national projections. A table with even a modest degree of detail offers a wealth of specific information on production techniques, distribution patterns, allocations to final uses, generation of national income, or foreign trade flows for a given industry or product.

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[1] Vladimir G. Treml, "Economic Interrelations in the Soviet Union," in Joint Economic Committee, 88th Cong., "Annual Economic Indicators for the U.S.S.R., Government Printing Office, Washington, D.C., 1964, pp. 183–213. An expanded discussion of the statistical data presented in the Annual Economic Indicators for the U.S.S.R. is found in Vladimir G. Treml, "The 1959 Soviet Intersectoral Flow Table," two volumes, Research Analysis Corp., technical paper 137, McLean, Va., 1964.

[2] For a general introduction to input-output analysis, see Hollis B. Chanery and Paul G. Clark, "Interindustry Economics," New York, 1959.

Unfortunately, the impressive amount of study in the U.S.S.R. on input-output techniques and the large number of prepared tables are not fully reflected in published information. To date, the Soviet statistical agencies have chosen to publish in the open literature only a segment of one of the four quadrants of one input-output table, the 1959 83-sector table in value terms, and assorted coefficient data. The growing interest in and expansion of input-output studies in the U.S.S.R. are also reflected in a constantly increasing number of references to input-output work and citations of individual measures or indexes by different authors in various sources. Western analysts, however, still do not have even one single complete Soviet input-output table.

Working under the auspices of the Research Analysis Corp. and with the help of its staff, the author of this study has found it possible to "reconstruct" the entire Soviet 1959 input-output table, using the published truncated segment of the interindustry transactions matrix and other fragmentary input-output data scattered throughout a score of Soviet books, journal papers, and even newspaper articles. The result of this study—a reconstructed version of the Soviet table showing 38 sectors (aggregated from the original 83)—was presented in the 1964 volume of the Joint Economic Committee, "Annual Economic Indicators for the U.S.S.R."[3] The main weakness of the reconstructed table, dictated by the amount of Soviet data available at that time, is the fact that two important quadrants of the table—final demand and value-added—are shown in terms of single entries for each of the 38 sectors. Thus, in the final demand quadrant, consumption, investment, and exports are represented by a single entry; similarly, a single entry in the value-added quadrant covers labor income, state income (profits and taxes), depreciation, and imports.

Additional data that have become available in Soviet statistical and other sources since the completion of the 1959 reconstruction have made it possible to improve on this aspect of the table, as well as to check the accuracy of the entire reconstruction.[4] The present paper and accompanying tables offer an expanded and corrected version of the 1959 reconstruction, as well as some new data that provide additional insight into the operation and overall capacity of the Soviet economy.

The Original 1959 Soviet Input-Output Table

The sources cited above provide detailed descriptions of this table. However, it is not inappropriate to give a brief summary here of the

[3] See footnote No. 1.

[4] One recent authoritative Soviet book, written by a team of input-output specialists, gives a highly aggregated—(seven branches)—version of the original 1959 83-sector input-output table. This is the first time since its completion that the table has been presented in Soviet literature in complete form, that is, with all three quadrants and with the overall totals. (A. Efimov and L. Berri, editors, "Metody planirovaniia mezhotraslevykh proportsii," Moscow, 1965, pp. 96–97.) Comparison of various entries in this table with the corresponding estimated entries of the reconstructed 38-sector table has revealed the following weighted errors in the reconstructed table:

First quadrant—0.8 percent.
Second quadrant—3.0 percent.
Third quadrant—6.0 percent.
Overall table—3.3 percent.

The most comforting aspect of this comparison is the relatively small error in the first quadrant. The errors found in the second and third quadrants are concentrated mainly in such sectors as agriculture, construction, and other nonindustrial activities and are thus easily correctable.

most important structural and classificational features of the Soviet table.

The original 1959 Soviet table, completed in 1961, is generally very close to the traditional, Leontief-type, static, open input-output table. It shows the production of 83 industries, or in Soviet terminology, sectors, and the distribution of their products and services to intermediate and final use. The 83 sectors include 73 industrial sectors (in Soviet statistical practice, mining is classified with industry), two agricultural sectors, three trade and distribution sectors, and one sector each for construction, transportation, communications, forestry, and other miscellaneous nonindustrial activities. Following the Soviet definition of national income, only "productive" activities are shown in the table. Thus various services such as health, financial activities, and entertainment are not separately identified, as is usually the case in Western input-output tables. Furthermore, the transportation sector covers freight transportation only, and communications refers to only communication services used by other "productive" activities. Passenger transportation, communications serving the population, and other services are not shown as independently identified activities in the interindustry transactions matrix but as claimants against final demand in the final-demand quadrant.

The table is organized in the form of three quadrants.[5] The largest, main-square quadrant presents the interindustry transactions of the 83 sectors: each row shows the distribution of the output of a given sector among interindustry uses, and each column shows, accordingly, that sector's purchases of the output of other industries. The northeast, or so-called final-demand quadrant shows the distribution of the output of the 83 sectors among "final" or autonomous uses, such as private and public consumption, gross investment, and exports. The southwest, or value-added quadrant shows depreciation and factor payments (labor income, profits, taxes) that originate in each of the 83 sectors, as well as imports.[6]

All flows and entries in the three-quadrant table are given in terms of current (1959) purchasers' prices, i.e., prices that include not only payments to the actual producers but also transportation and distribution costs, and turnover taxes whenever applicable. Use of purchasers' prices, which are usually considered by input-output specialists to be inferior to producers' prices, results in double counting of trade and transportation costs, and in distortion of actual physical product flows due to the fact that turnover tax rates in the U.S.S.R. differ substantially for different users.

The data for the 83 sectors identified in the table have been adjusted for the nonsectoral output that is frequently found in Soviet enterprises; i.e., output that is not primary for the given sector has been removed and added to the sector for which it is primary; input flows have also been adjusted accordingly.

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[5] Actually, the original Soviet table was prepared in terms of four quadrants. However, many Soviet economists expressed dissatisfaction with the layout of the fourth quadrant, and no information about it has been made available. It has since been omitted from subsequent Soviet input-output tables.

[6] The Soviet table differs in format from its Western counterparts in two respects. All construction, both new and maintenance, is classified as investment and appears in the final-demand quadrant. Thus the construction row in the interindustry transactions matrix has only zero entries. On the other hand, the entire output of the transportation, communications, and distribution sectors is allocated within the interindustry transactions matrix, and the contribution of these sectors to final demand is, by definition, zero.

The basic, or flow, table is complemented by two additional tables of coefficients. One, the table of direct input coefficients, is a square 83 by 83 matrix giving the inputs of supplying sectors per unit of output of the producing sectors. The second is also a square 83 by 83 matrix showing the "full" or "total" input coefficients. The latter reflect not only the amount of a given input used in the production of a unit of the given output but also trace all the indirect requirements for this input; e.g., not only the coal used directly in the production of, let us say, automobiles, but also the coal used in the production of automobile tires that are then purchased by the automobile sector.

After the 1959 table in value terms was completed, Soviet statistical agencies also prepared labor employment data (in man-years) for each of the 83 sectors identified in the table.

Reconstruction of the 1959 Table in Value Terms

The Soviet 1959 table has never been published in complete form. The 1961 Statistical Yearbook carried a truncated segment of the interindustry transactions matrix, with some sectors being completely omitted and some aggregated for publication.[7] Except for some summary indexes, no data pertaining to the final-demand or value-added quadrants have been released. The usefulness of the published segment was therefore rather limited. Complete omission of the two bordering quadrants and the absence of any gross output totals precluded use of the published data as an input-output table; the unknown magnitudes of the omissions reduced the usefulness of the published interindustry transactions matrix for analysis of individual sectors.[8]

Using fragmentary data found in various Soviet sources and by different methods of estimation, the author of this study found it possible to reconstruct the entire 1959 Soviet table in aggregated form. The original 83 sectors were grouped into 38, and the bordering quadrants were presented in terms of one column and one row of entries for each of the 38 aggregated sectors.[9]

As was pointed out above, data that became available subsequent to completion of the reconstruction enabled the author to improve the reconstructed table by correcting certain errors and by separating the most important categories of the value-added and final-demand quadrants. The value-added quadrant now contains separately identified entries for depreciation, labor income, other net income, and imports. Final demand in the new version shows public consumption, private consumption, gross investment, and exports.

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[7] The following three sectors were omitted entirely: radioelectronics, miscellaneous products of machine building, and miscellaneous products of industry. Thirteen others were aggregated into five sectors, with each of the following groups comprising one sector: four metallurgy sectors, two chemicals sectors, two bread and flour sectors, the transportation and the communications sectors, and the three trade and distribution sectors. See annex table below.

[8] The difficulty of using the published Soviet segment of the interindustry transactions table was compounded by the fact that at the time of publication the omissions and aggregations were not identified or explained; the analyst was simply confronted with the fact that the interindustry transactions matrix prepared originally in terms of 83 sectors was published in the form of 73 sectors. Subsequent analysis of other Soviet data showed that the published truncated segment omitted flows amounting to 6.4 billion rubles in value or 4.2 percent of the interindustry total.

[9] See above, footnote No. 1. The number of sectors shown in the reconstructed table, as well as the format of the table, was dictated essentially by the availability of additional Soviet input-output data found in other Soviet sources, and by the importance of the industries in question. Thus the importance of the metal sectors appeared to be sufficiently great to attempt to break down the aggregated sector into four separate sectors.

The new version of the reconstructed flow table (table *a* below) has 1,786 entries, not counting the various totals and subtotals; of these, 608 have been estimated. The process of estimating the omitted entries, verifying the estimates, and checking the overall totals has been, needless to say, a lengthy and tedious effort. Detailed descriptions of the estimating methods and the various statistical appendixes were deemed too long for inclusion in this paper and are being made available to interested specialists in a separate publication.[10] Thus this paper contains only the final product of the study: the reconstructed table with some necessary explanatory notes.

Explanatory Notes on the 1959 Soviet Input-Output Table as Reconstructed

The reconstructed version of the 1959 Soviet input-output table is presented in a series of three tables below. Table *a* shows the absolute values of the output flows in the economy; table *b* gives the direct input coefficients per unit of output as derived from the interindustry transactions matrix of table *a;* table *c* is the inverse of table *b* and shows the full (direct plus indirect) input coefficients.

The commodity-sector classification employed in these tables conforms to the original Soviet 83-sector classification but is aggregated to 38 sectors. A detailed list of products included in each of the 38 sectors, as well as the aggregation code used by the author in reducing the original Soviet 83 by 83 table to the 38 by 38 size, are given in the Annex Table.

Table *a* is the traditional Leontief-type flow table and is composed of three main sections, or quadrants, as follows:

1. The interindustry transactions matrix is the central section, a square 39 by 39 table showing interindustry purchases and distribution of the output of each of the 38 sectors separately identified in the table, as well as the interindustry subtotals (col. 39 and row 39).

2. The final-demand or northeast quadrant shows deliveries of output to final, or autonomous demand, broken down into four separate categories:

Private consumption (col. 40) covers all commodities for consumption purposes purchased by the population in retail trade outlets and other markets, plus consumption of agricultural commodities produced on private plots and/or distributed to the population in kind. It also includes consumption of fuel, gas, and electrical power in residential housing.[11] The estimated value of depreciation of privately owned residential housing completes the column.[12]

Public consumption (col. 41) includes consumption by all governmental, education, and other public organizations, including the consumption of fuel, electrical power, and other material inputs in passenger transportation and communications serving the public and in

[10] Vladimir G. Treml, "Value Added and Final Demand Quadrants in the 1959 Soviet Input-Output Table—Notes on Reconstruction," in John P. Hardt, editor, *Selected Studies in Soviet Economic Trends, Structure, and Institutions,* Research Analysis Corp., McLean, Va., 1966.

[11] Purchases by the population of construction materials for capital construction of private housing, and additions to privately owned livestock, are included under gross investment.

[12] The term "estimated" is used here (and in the next category—public consumption) to distinguish this fictitious entry from other "consumption" entries. Depreciation of privately owned housing (as well as that of public facilities financed through the state budget) is an accounting entry that reflects the actual wear and tear of properties but is not financed or "funded" in any way.

other "nonproductive" activities. The last entry in the column shows the estimated value of depreciation of public facilities.

Gross investment (col. 42) comprises all new machinery and equipment delivered on capital account to all enterprises and government organizations, all machinery and equipment used in capital repair, and all new and maintenance construction (including net changes in unfinished construction). It also includes net changes in stocks, inventories, and state reserves,[13] as well as losses due to spoilage and accidental destruction of output.

Exports (col. 43) covers all commodity trade exports.[14]

3. The value-added or southwest quadrant is broken down into the following four categories:

Depreciation (row 40), or capital consumption allowances, as actually recorded and paid by state enterprises, producers' cooperatives, and collective farms at rates fixed by the state.

Labor income (row 41) comprises wages, salaries, bonuses, various leave payments to individuals paid by state enterprises, money income and income-in-kind (valued in average market prices) of collective farm members, and money income derived from private agricultural plots. It also includes social security contributions paid by state enterprises.[15]

Other net income (row 42) is a heterogeneous category which includes the following elements of net product:

(1) Profits earned by state enterprises, including all planned and unplanned profits, and losses covered by state subsidies (shown in the table with minus sign);

(2) Turnover taxes and other minor indirect taxes;[16]

(3) Residual income of collective farms and producers' cooperatives (net income after payment of all material purchases and members' claims);

(4) Miscellaneous elements of net product, such as interest payments on short-term loans, fines, and penalties paid by state enterprises, special funds of producers' cooperatives, surplus in administrative expenditure accounts paid into the state budget, costs of on-the-job labor training, and the like.

National income (row 43) is, by Soviet definition, the sum of labor income (row 41) and other net income (row 42).

Imports (row 44) covers both competing and noncompeting imports classified with sectors producing similar products domestically.[17]

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[13] Many Western specialists hold that Soviet state reserves include stockpiles of military hardware, munitions, and other defense items. Purchases of materials (food, uniforms, fuel, etc.) by the military establishment on current account are included in either public or private consumption.

[14] Following standard Soviet practice, exports are recorded in terms of domestic prices net of turnover taxes.

[15] One problem which unfortunately cannot be resolved without additional information is the treatment in input-output tables of "value added" created in residential construction undertaken by private individuals, which constitutes a sizable share of total residential construction. In the absence of Soviet information on this point it is equally reasonable to expect this category of "value added" to be shown as "labor income" (technically speaking, Soviet citizens, especially in rural areas, are personally engaged in the construction effort), or as "other income." The latter assumption was used in the reconstructed table.

[16] About 60 percent of all turnover taxes in the U.S.S.R. are collected at the producers' level, and the remaining 40 percent are collected through the state consumer trade and distribution system. All evidence indicates that in national input-output tables the turnover tax is attributed entirely to the producing sector, and this is the procedure followed in the reconstructed table.

[17] Following standard Soviet statistical practice, imports are valued at domestic prices, including turnover tax whenever applicable.

Total outlays (row 45) is the sum of material purchases (row 39) depreciation (row 40), national income (row 43), and imports (row 44).

Employment (row 46) shows total employment (averaged for the year) in each sector, expressed in thousands of man-years.

Table *a*, the so-called technology matrix, shows direct material input coefficients, defined as inputs of industry (i), per ruble of gross output of industry (j).

Table *c*, the so-called "Leontief inverse" of the technology matrix, shows full or total input coefficients of industry (i) into industry (j), defined as the direct and indirect requirements for inputs of industry (i) per ruble of output of industry (j) delivered to final demand.

Correspondence of Input-Output Totals With Official Soviet National Income and Product Statistics

Soviet input-output tables are completely integrated with national income and product accounts, and it would, therefore, be interesting to reconcile the various totals shown in the reconstructed 38-sector table with the available income statistics. Close correspondence between the two sets of data does not formally constitute proof of the accuracy of the reconstructed table but it is instructive. Soviet national income statistics have heretofore been very meager and highly aggregated; the availability of corresponding input-output data thus opens to a Western analyst a new dimension in the study of Soviet national income accounts.

The official Soviet national income statistics (by use) for 1959 have been reported as follows: [18]

	Billions of current rubles
Private consumption	88.0
Public consumption	9.2
Net investment in fixed capital	22.5
Net investment in stocks and resources	13.6
Total national income	133.3

We can compare these figures with corresponding figures derived from the final-demand quadrant of the reconstructed 38-sector input-output table:

	Millions of current rubles
Private material consumption	85,175.0
Depreciation of private capital funds	2,825.5
Public consumption	6,999.3
Depreciation of public capital funds	2,094.5
Total consumption	97,094.3
Gross investment and losses	54,084.2
Less productive depreciation	8,983.8
Less depreciation of private capital funds	2,825.5
Less depreciation of public capital funds	2,094.5
Less export-import balance	3,835.8
Net investment	36,344.6
Total national income by use	133,438.9

[18] TsSU, "Narodnoe khoziaistvo SSSR v 1960 godu," Moscow, 1961, p. 154.

As can be seen, the total of 133.4 billion rubles agrees closely with the independently reported official national income of 133.3 billion rubles.

A more significant test of the accuracy of our reconstruction of the final demand and value-added quadrants is based on the following comparison. Soviet official statistical sources publish each year the distribution of relative shares of national income and gross social product ("sovokupnyi obshchestvennyi produkt") generated in different sectors of the national economy. We can rearrange and adjust the input-output flow data to agree with the definitions of the national income and product accounts and then compare the distribution derived on the basis of the input-output table with the offical distribution.

Two adjustments are necessary. First, Soviet national income and gross social product are both prepared in terms of wholesale industry prices, that is, prices which include turnover tax but exclude trade and transportation charges,[19] while the input-output flow table measures the flows in retail, or final consumption prices, which include all distribution costs. Thus, trade and transportation charges must be removed from the input-output flows to make them comparable to national income and product accounts.

The second adjustment deals with foreign trade and is more intricate, because Soviet literature on the subject is not very clear and the methodology used by the Central Statistical Administration must be deduced from different sources. In the first place, all published Soviet statistics on foreign trade show exports and imports in "foreign trade rubles," that is, in terms of world market prices and world market currencies converted into rubles by applying the official Soviet foreign exchange rate. Since the Soviet domestic market is completely isolated from world markets, the official foreign trade statistics derived in this way differ substantially from domestic values of exported and imported goods. The difficulty is further compounded by the fact that both for the purposes of national income accounting and in construction of input-output tables exports in domestic prices are measured net of the turnover tax and imports in domestic prices are measured with the turnover tax included. The price differentials and especially the treatment of the turnover tax create a substantial surplus for Soviet state foreign trade agencies.[20] A review of Soviet literature on the subject indicates that this net surplus (income from sales of imported goods less payments to producers of goods for exports) is added to the value of output of the trade sector in national income accounting.[21]

Thus to convert the totals shown in an input-output table to gross social product totals, the following adjustments must be made:

Gross output in purchaser's prices from the input-output table;
- less: transportation, communications and trade costs;
- less: imports in domestic values from respective sectors;
- plus: net foreign trade balance (imports less exports) to the trade sector;
- equals: Gross social product in wholesale prices.

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[19] See A. I. Petrov, *Kurs ekonomicheskoi statistiki*, 5th edition, Moscow, 1961.

[20] This net surplus (imports less exports) amounted to 3.8 and 5.9 billion rubles in 1959 and 1962, respectively. A. N. Efimov and L. Ia. Berri (eds.), *Metody planirovaniia mezhotraslevykh proportsii*, Moscow, 1965, pp. 97 and 114.

[21] See for instance, M. Z. Bor, *Balans narodnogo khoziaistva SSSR*, Moscow, 1956, pp. 39–40, and by the same author, *Planovyi balans narodnogo khoziaistva SSSR*, Moscow, 1959, pp. 69–70. The fact that the import-export balance is added to the value of gross social product (domestic) and to national income is clearly shown in B. A. Volchkov, in *Ekonomika i matematicheskie metody*, No. 3, 1966, pp. 433–435; however, the author does not say to which specific sector of the economy the surplus is imputed.

The calculations for five aggregate sectors based on the reconstructed 1959 Soviet input-output table are shown in the following table.

Conversion of input-output totals to gross social product totals

[Millions of current 1959 rubles]

Sector	Gross output from I/O table	Transportation and trade costs	Foreign trade adjustment	GSP in wholesale prices
Industry	196,899.9	−18,737.9	−7,800.0	170,362.0
Construction	29,200.0	0	0	29,200.0
Agriculture	53,500.0	−3,619.8	−1,300.0	48,580.2
Transportation and communications	11,256.2	0	0	11,256.2
Trade and other [1]	14,671.9	−96.7	+3,835.0	18,410.2
Total	305,528.0	−22,454.4		277,808.6

[1] Includes trade, state supply and distribution, procurement of agricultural products, forestry, and other branches of material production.

Our estimate of 277.8 billion rubles for the value of gross social product in 1959 agrees closely with the available fragmentary Soviet data. A recent statistical source reported the value of gross social product in current prices as 259.3 and 303.8 billion rubles for 1958 and 1960, respectively.[22] While the value of GSP for 1959 was not reported it can be approximately estimated at 280 billion rubles, using the official GSP index and disregarding possible price changes.[23]

We can now compare the relative shares of the five aggregate sectors derived on the basis of the input-output table with the officially published data:

Relative shares of different sectors in GSP

[Percent of total]

	Based on input-output table	Official Soviet data [24]
Industry	61.32	61.3
Construction	10.51	10.5
Agriculture	17.49	17.5
Transportation and communications	4.05	4.1
Trade and other	6.63	6.6
Total	100.0	100.0

[24] Soviet national income and product statistics are notorious for unexplained changes. Thus, the distribution of GSP in 1959 was reported in 3 consecutive statistical yearbooks as follows:

[In percent]

	A	B	C
Industry	61.3	61.5	61.4
Construction	10.5	10.4	10.3
Agriculture	17.5	17.4	17.3
Transportation and communications	4.1	4.1	4.1
Trade and other	6.6	6.6	6.9

A. Ts.S.U., Narodnoe khoziaistvo SSSR v 1959 godu, Moscow, 1960, p. 78.
B. Ts.S.U., Narodnoe khoziaistvo SSSR v 1960 godu, Moscow, 1961, p. 102.
C. Ts.S.U., Narodnoe khoziaistvo SSSR v 1961 godu, Moscow, 1962, p. 76.
The *A* variant was chosen for the comparison above as the one published in the U.S.S.R. closest to the preparation of the 1959 Soviet input-output table.

[22] Ts.S.U., *Narodnoe khoziaistvo SSSR v 1964 godu*, Moscow, 1965, p. 67.
[23] *Ibid.*, p. 65.

The identity of the distribution based on the reconstructed input-output data and the official Soviet distribution is striking and supports the accuracy of our reconstruction.

A similar test applied to the distribution of national income is less satisfactory because the reconstructed input-output table does not give us sufficient data to make the necessary adjustments. The only adjustment we can make is to add to the value of net output of the trade branch the import-export surplus, as was done in the case of the distribution of gross social product. The two distributions are then as follows:

Relative national income shares

[In percent]

	On the basis of input-output [25]	Official Soviet [26]
Industry	52.84	52.7
Construction	10.21	10.2
Agriculture	20.85	20.9
Transportation and communications	4.80	4.8
Trade and other	11.30	11.4
Total	100.0	100.0

[25] The national income data are taken directly from the 1959 reconstructed input-output table with 1 exception: the net foreign trade surplus of 3,835,800,000 rubles was added to the value of output in the trade sector.

[26] As with gross social product data, national income shares for 1959 were reported differently in 3 consecutive yearbooks:

	A	B	C
Industry	52.7	52.6	52.3
Construction	10.2	9.9	9.5
Agriculture	20.9	21.2	21.3
Transportation and communications	4.8	4.8	4.8
Trade and other	11.4	11.5	12.1

A. Ts.S.U., Narodnoe khoziaistvo SSSR v 1959 godu, Moscow, 1960, p. 78.
B. Ts.S.U., Narodnoe khoziaistvo SSSR v 1960 godu, Moscow, 1961, p. 153.
C. Ts.S.U., Narodnoe khoziaistvo SSSR v 1961 godu, Moscow, 1962, p. 76.
The *A* variant was again chosen for the above comparison as being the one closest in time to the preparation of the original 1959 input-output table.

Although less satisfactory due to the use of unadjusted data and showing less agreement with the official Soviet national income data, the comparison of the relative shares of national income generated in aggregate sectors shows sufficient similarity to provide yet another proof of the accuracy of the overall reconstruction of the 1959 input-output table.

Reconstructed 1959 Soviet Input-Output Table

a. Full Input Coefficients, Technology Matrix $(I-A)^{-1}$

Producing sector \ Using sector	1 Ferrous ores	2 Ferrous metals	3 Nonferrous ores	4 Nonferrous metals	5 Coking coal	6 Metal products	7 Coal	8 Oil	9 Gas	10 Other fuels	11 Electrical power	12 Electrical & power M&E	13 Tools & instruments	14 General machinery	15 Transportation M&E	16 Automobiles	17 Agricultural M&E	18 Machinery n.e.c.	19 Metal working	20 Repair of machinery	21 Abrasives	22 Mineral & basic chemicals	23 Synthetics, paints	24 Rubber products	25 Lumber & woodworking	26 Paper	27 Construction materials	28 Glass	29 Textiles	30 Apparel and footwear	31 Food	32 Industry n.e.c.	33 Construction	34 Agriculture	35 Forestry	36 Transport and comm.	37 Trade & distribution	38 Products n.e.c.
1 Ferrous ores	1.00383	0.09524	0.00211	0.01576	0.00110	0.05404	0.00109	0.00060	0.00041	0.00124	0.00064	0.01183	0.00518	0.01144	0.00853	0.00456	0.01472	0.02206	0.01250	0.00808	0.01937	0.00305	0.00144	0.00110	0.00123	0.00114	0.00396	0.00909	0.00028	0.00034	0.00048	0.00169	0.00477	0.00049	0.00035	0.00110	0.00063	0.00019
2 Ferrous metals	0.03809	1.17618	0.03834	0.01994	0.01817	0.51382	0.01835	0.01004	0.00726	0.02088	0.01121	0.20806	0.06147	0.21710	0.15963	0.10974	0.17001	0.03133	0.24574	0.14612	0.03128	0.02468	0.01448	0.01337	0.01806	0.01805	0.05690	0.02737	0.00449	0.00514	0.00814	0.02980	0.08602	0.00828	0.00591	0.01784	0.01059	0.00293
3 Nonferrous ores	0.00233	0.02567	1.00306	0.24508	0.00151	0.01352	0.00193	0.00094	0.00056	0.00194	0.00103	0.02699	0.01225	0.01449	0.01374	0.01691	0.00876	0.00621	0.01326	0.01407	0.02867	0.00660	0.00930	0.00429	0.00190	0.00172	0.00820	0.00789	0.00054	0.00064	0.00075	0.00369	0.00476	0.00080	0.00040	0.00191	0.00093	0.00026
4 Nonferrous metals	0.01065	0.12272	0.03956	1.17424	0.00694	0.06435	0.00719	0.00436	0.00261	0.00913	0.00485	0.12695	0.05761	0.15421	0.07855	0.06506	0.08072	0.04167	0.02958	0.06326	0.06494	0.03321	0.01946	0.04379	0.02022	0.00700	0.00784	0.02101	0.01339	0.00254	0.00300	0.00348	0.01736	0.01924	0.00369	0.00173	0.00898	0.00440	0.00120
5 Coking coal	0.01820	0.15078	0.00651	0.05437	1.07647	0.08614	0.00371	0.00345	0.00179	0.00596	0.00226	0.01450	0.01576	0.01736	0.02568	0.02149	0.02844	0.00865	0.04569	0.02657	0.01864	0.04385	0.02059	0.00901	0.00942	0.00959	0.01139	0.00567	0.00126	0.00149	0.00170	0.00660	0.01380	0.00195	0.00147	0.00358	0.00200	0.00072
6 Metal products	0.01047	0.02095	0.00673	0.01046	0.00549	1.04401	0.00550	0.00247	0.00141	0.00561	0.00293	0.01925	0.01137	0.02192	0.01376	0.01828	0.01688	0.00543	0.02001	0.02035	0.00719	0.00882	0.00321	0.00637	0.00939	0.00592	0.01145	0.01588	0.00127	0.00198	0.00164	0.00286	0.01401	0.00162	0.00141	0.00555	0.00293	0.00143
7 Coal	0.08102	0.26725	0.03978	0.09363	0.93209	0.17756	1.19410	0.03557	0.05527	0.04863	0.27552	0.08242	0.03529	0.08383	0.06550	0.05325	0.06498	0.01900	0.08856	0.07043	0.08617	0.12652	0.05462	0.03544	0.03926	0.09267	0.10861	0.06412	0.01083	0.01176	0.01543	0.02874	0.04952	0.00976	0.00590	0.10022	0.01768	0.00944
8 Oil	0.03718	0.05329	0.04815	0.05511	0.04365	0.05842	0.04315	1.21923	0.02525	0.05196	0.09869	0.04003	0.01935	0.04098	0.03152	0.03414	0.03103	0.01180	0.03156	0.04052	0.07075	0.07861	0.05879	0.04035	0.04968	0.04942	0.07599	0.05102	0.01340	0.01297	0.02511	0.02301	0.04417	0.03789	0.02505	0.11455	0.01086	0.00802
9 Gas	0.00143	0.00160	0.00119	0.00227	0.00197	0.00306	0.00080	0.00107	1.00070	0.00166	0.01957	0.00145	0.00047	0.00129	0.00116	0.00117	0.00124	0.00050	0.00095	0.00125	0.00281	0.00225	0.00544	0.00245	0.00052	0.00116	0.00310	0.00177	0.00035	0.00037	0.00030	0.00086	0.00139	0.00019	0.00009	0.00063	0.00022	0.00013
10 Other fuels	0.00450	0.00551	0.00218	0.00629	0.01949	0.00600	0.00294	0.00292	0.04747	1.04318	0.06947	0.00430	0.00215	0.00725	0.00437	0.00260	0.00310	0.00165	0.00371	0.00349	0.00690	0.00648	0.00421	0.00337	0.00497	0.01303	0.00902	0.01915	0.00189	0.00191	0.00109	0.00252	0.00389	0.00064	0.00029	0.00191	0.00128	0.00088
11 Electrical power	0.05642	0.04403	0.02336	0.07604	0.05829	0.06032	0.03920	0.03869	0.01313	0.05097	1.01640	0.04237	0.02311	0.03824	0.02910	0.01960	0.01742	0.01416	0.02608	0.03784	0.09127	0.07431	0.04013	0.03368	0.01992	0.04418	0.05283	0.02726	0.00914	0.00967	0.00747	0.02177	0.02458	0.00667	0.00277	0.02337	0.00861	0.00464
12 Electrical & power M&E	0.00630	0.00470	0.00550	0.00376	0.00451	0.00442	0.00444	0.00228	0.00214	0.00902	0.00501	1.08609	0.00948	0.05909	0.13276	0.00900	0.01181	0.06220	0.00811	0.02288	0.00416	0.00551	0.00294	0.00229	0.00274	0.00322	0.00448	0.00345	0.00124	0.00125	0.00190	0.00987	0.00760	0.00284	0.00045	0.00383	0.00285	0.00074
13 Tools & instruments	0.01003	0.00765	0.00892	0.00579	0.00767	0.01362	0.00844	0.00280	0.00283	0.01351	0.00492	0.04071	1.03527	0.03545	0.02883	0.01701	0.02654	0.04577	0.00780	0.03099	0.00846	0.00763	0.00329	0.00382	0.00512	0.00931	0.00868	0.00508	0.00124	0.00131	0.00186	0.01177	0.02350	0.00229	0.00069	0.00525	0.00231	0.00057
14 General machinery	0.01990	0.01405	0.01867	0.01119	0.01061	0.01292	0.01241	0.00571	0.00337	0.01701	0.00468	0.00565	0.00319	1.05202	0.01002	0.00360	0.00494	0.00367	0.00492	0.00934	0.00430	0.00908	0.00403	0.00359	0.00436	0.00865	0.00996	0.00418	0.00288	0.00254	0.00177	0.00688	0.00663	0.00111	0.00041	0.00243	0.00552	0.00065
15 Transportation M&E	0.00423	0.00359	0.00264	0.00235	0.00458	0.00345	0.00486	0.00358	0.00073	0.00557	0.00210	0.00179	0.00100	0.00522	1.04893	0.00162	0.00186	0.00197	0.00237	0.01950	0.00220	0.00754	0.00150	0.00137	0.00386	0.00271	0.00595	0.00288	0.00060	0.00063	0.00111	0.00336	0.00217	0.00117	0.00048	0.01532	0.00093	0.00059
16 Automobiles	0.01018	0.00783	0.00736	0.00560	0.00823	0.00804	0.00879	0.00634	0.00214	0.00724	0.00461	0.00584	0.00446	0.03870	0.00919	1.11740	0.00964	0.02082	0.00590	0.07869	0.00626	0.01441	0.00383	0.00415	0.01510	0.00775	0.01413	0.00706	0.00162	0.00163	0.00301	0.01136	0.00827	0.00382	0.00097	0.02332	0.00160	0.00139
17 Agricultural M&E	0.00424	0.00281	0.00382	0.00239	0.00192	0.00247	0.00184	0.00136	0.00122	0.01135	0.00246	0.01043	0.00094	0.02533	0.00496	0.00126	1.08954	0.01430	0.00198	0.06141	0.00255	0.00236	0.00176	0.00140	0.00886	0.00339	0.00380	0.00298	0.00156	0.00123	0.00291	0.00780	0.00396	0.00627	0.01298	0.00136	0.00077	0.00033
18 Machinery n.e.c.	0.00533	0.00767	0.00358	0.00466	0.01777	0.00660	0.02086	0.00979	0.00775	0.04331	0.01480	0.01537	0.00349	0.02745	0.03017	0.00720	0.01010	1.02963	0.00402	0.01815	0.00492	0.01706	0.00720	0.00724	0.00429	0.00546	0.02275	0.00557	0.00375	0.00351	0.00849	0.01694	0.01407	0.01293	0.00094	0.01020	0.01348	0.00076
19 Metal working	0.00420	0.00307	0.00375	0.00234	0.00314	0.00399	0.00353	0.00084	0.00054	0.00221	0.00163	0.01097	0.00184	0.01060	0.02505	0.00727	0.00320	0.00178	1.01765	0.01436	0.00512	0.00442	0.00486	0.00481	0.01243	0.00471	0.00447	0.01485	0.00232	0.00349	0.00344	0.01360	0.04490	0.00469	0.01071	0.00144	0.00119	0.00053
20 Repair of machinery	0.04372	0.02656	0.04035	0.02369	0.00801	0.02067	0.00525	0.00914	0.00868	0.00627	0.01937	0.01247	0.00746	0.01170	0.01031	0.00914	0.00774	0.00255	0.00923	1.00686	0.03142	0.01700	0.01472	0.00973	0.00976	0.00832	0.02148	0.03251	0.00699	0.00566	0.01593	0.01803	0.00802	0.02682	0.00119	0.01060	0.00154	0.00095
21 Abrasives	0.00264	0.00111	0.00251	0.00115	0.00029	0.00219	0.00032	0.00016	0.00011	0.00055	0.00029	0.02257	0.00274	0.00309	0.00524	0.00172	0.00220	0.00150	0.00132	0.00191	1.07448	0.00040	0.00053	0.00034	0.00086	0.00047	0.00050	0.00215	0.00011	0.00021	0.00017	0.00042	0.00087	0.00028	0.00006	0.00023	0.00027	0.00005
22 Mineral & basic chemicals	0.01367	0.01364	0.01467	0.01031	0.01678	0.01221	0.00311	0.00991	0.00292	0.00703	0.00343	0.01526	0.00413	0.00918	0.00962	0.01000	0.00944	0.00459	0.00756	0.00850	0.03939	1.13195	0.06506	0.02678	0.00516	0.02045	0.00460	0.00603	0.00374	0.00436	0.00546	0.02280	0.00432	0.01107	0.01075	0.00396	0.00259	0.00169
23 Synthetics, paints	0.01740	0.01458	0.01381	0.01061	0.01370	0.01624	0.01389	0.01132	0.00843	0.01282	0.00670	0.05398	0.03707	0.03590	0.03451	0.08364	0.03680	0.02380	0.02402	0.03941	0.01401	0.05482	1.27036	0.44714	0.02477	0.01647	0.01740	0.02503	0.02478	0.03082	0.00563	0.07189	0.02022	0.00580	0.00207	0.02593	0.00700	0.00757
24 Rubber products	0.01583	0.01444	0.01077	0.00948	0.01853	0.01411	0.02016	0.01112	0.00810	0.01562	0.00736	0.01820	0.00838	0.03698	0.01758	0.15786	0.05430	0.01481	0.01044	0.02573	0.00876	0.02427	0.00900	1.12362	0.02032	0.01261	0.02128	0.01015	0.00385	0.00534	0.00398	0.03088	0.01145	0.00368	0.00207	0.04278	0.00770	0.00314
25 Lumber & woodworking	0.09210	0.04562	0.04387	0.03009	0.08900	0.05735	0.10963	0.01693	0.01248	0.04591	0.03151	0.03801	0.02268	0.03958	0.05648	0.03053	0.03545	0.01746	0.02627	0.05627	0.02399	0.04679	0.04681	0.03507	1.34047	0.38211	0.05319	0.06889	0.00952	0.01626	0.01981	0.04053	0.15426	0.01147	0.00773	0.03463	0.04650	0.02342
26 Paper	0.00468	0.00594	0.00442	0.00601	0.00282	0.01668	0.00307	0.00765	0.00358	0.00187	0.00179	0.01005	0.00575	0.00505	0.00439	0.00598	0.00503	0.00358	0.00551	0.00432	0.00613	0.01068	0.01755	0.00906	0.00509	1.07791	0.01068	0.01353	0.00388	0.00683	0.00862	0.03220	0.00567	0.00493	0.00194	0.00215	0.05579	0.05918
27 Construction materials	0.00736	0.00438	0.00629	0.00346	0.00480	0.00535	0.00528	0.00294	0.00153	0.00350	0.00250	0.00504	0.00188	0.00434	0.01115	0.00280	0.00275	0.00075	0.00415	0.01149	0.00724	0.00784	0.00278	0.00227	0.00386	0.00922	1.21450	0.01145	0.00096	0.00107	0.00142	0.00144	0.22417	0.00125	0.00399	0.00775	0.00083	0.00082
28 Glass	0.00157	0.00087	0.00125	0.00072	0.00088	0.00100	0.00090	0.00041	0.00019	0.00072	0.00048	0.00688	0.00377	0.00165	0.00332	0.00598	0.00304	0.00085	0.00219	0.00295	0.00140	0.00203	0.00805	0.00312	0.00534	0.00208	0.00088	1.01573	0.00032	0.00046	0.00141	0.00106	0.01218	0.00039	0.00011	0.00108	0.00030	0.00019
29 Textiles	0.02719	0.02681	0.02237	0.01915	0.02967	0.06330	0.03221	0.01605	0.00932	0.03058	0.01370	0.04105	0.02606	0.03193	0.03370	0.06797	0.03748	0.01944	0.02155	0.03322	0.15060	0.04023	0.03565	0.31014	0.05839	0.03976	0.02695	0.03267	1.32555	0.60877	0.01479	0.02659	0.02926	0.01067	0.00275	0.03031	0.05728	0.01493
30 Apparel and footwear	0.02343	0.02393	0.02038	0.01606	0.03136	0.03451	0.03405	0.00689	0.00760	0.03793	0.01426	0.01624	0.01062	0.02059	0.01798	0.02147	0.01647	0.00343	0.01660	0.01737	0.01802	0.02951	0.01309	0.01027	0.02643	0.01821	0.01740	0.01955	0.00382	1.14380	0.00674	0.00643	0.03010	0.00531	0.00198	0.01253	0.01138	0.00202
31 Food	0.00686	0.00590	0.00582	0.00436	0.00541	0.00659	0.00485	0.00290	0.00226	0.00510	0.00274	0.01403	0.00789	0.01019	0.01005	0.01575	0.00388	0.00466	0.00564	0.00844	0.03601	0.03199	0.14803	0.06141	0.01040	0.00701	0.00840	0.00634	0.01552	0.06321	1.32147	0.20768	0.01000	0.05304	0.00148	0.00473	0.00365	0.00135
32 Industry n.e.c.	0.00079	0.00063	0.00067	0.00047	0.00068	0.00072	0.00069	0.00040	0.00022	0.00091	0.00037	0.01089	0.00571	0.01094	0.00997	0.01047	0.00996	0.00486	0.00650	0.00221	0.00082	0.00532	0.00431	0.00630	0.00069	0.00065	0.01609	0.00058	0.00215	0.00290	0.00141	1.00122	0.00348	0.00346	0.00028	0.00086	0.00033	0.00011
33 Construction	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000
34 Agriculture	0.00970	0.00949	0.00791	0.00488	0.01076	0.01783	0.01143	0.00527	0.00321	0.01062	0.00689	0.01541	0.00888	0.01224	0.01262	0.02155	0.01240	0.00630	0.00774	0.01127	0.04492	0.02322	0.06733	0.08785	0.02277	0.01460	0.01140	0.01092	0.27367	0.18847	0.49405	0.13230	0.01248	1.32524	0.02074	0.01101	0.01370	0.00386
35 Forestry	0.00070	0.00071	0.00059	0.00055	0.00118	0.00081	0.00146	0.00022	0.00017	0.00061	0.00042	0.00056	0.00034	0.00058	0.00080	0.00044	0.00055	0.00025	0.00041	0.00078	0.00033	0.00063	0.00072	0.00053	0.01771	0.00541	0.00077	0.00099	0.00013	0.00026	0.00028	0.00084	0.00444	0.00016	1.02065	0.00047	0.00064	0.00570
36 Transport and comm.	0.19454	0.18492	0.09265	0.10625	0.29615	0.18116	0.32005	0.23684	0.02965	0.16445	0.10351	0.09593	0.04594	0.11641	0.07137	0.09157	0.11127	0.02593	0.14536	0.07091	0.10748	0.49557	0.07867	0.07824	0.23778	0.14760	0.35048	0.15323	0.02960	0.03416	0.05245	0.05367	0.11644	0.03911	0.03169	1.06385	0.03130	0.03961
37 Trade & distribution	0.04872	0.06543	0.04674	0.06201	0.03541	0.07453	0.04208	0.12877	0.04073	0.01801	0.02478	0.04605	0.03353	0.03326	0.02587	0.04310	0.01343	0.02554	0.05832	0.02572	0.02646	0.04241	0.04395	0.04263	0.06572	0.10376	0.07910	0.12001	0.05542	0.08098	0.11701	0.16407	0.03450	0.08149	0.00594	0.02091	1.01152	0.01125
38 Products n.e.c.	0.00188	0.01999	0.00170	0.02830	0.00127	0.01031	0.00133	0.00109	0.00063	0.00145	0.00076	0.01031	0.00678	0.01111	0.01025	0.00751	0.01241	0.00394	0.01231	0.00755	0.00222	0.00300	0.01800	0.01311	0.00144	0.06753	0.01200	0.01472	0.00093	0.00769	0.03296	0.05731	0.01407	0.00121	0.00050	0.00147	0.00398	1.00386
39 Labor input coefficients	0.46716	0.39837	0.32901	0.31829	0.44772	0.41522	0.47426	0.24027	0.14402	0.42285	0.29603	0.41031	0.26934	0.41989	0.37149	0.29559	0.35349	0.43194	0.43339	0.50775	0.42617	0.47186	0.29741	0.28275	0.56437	0.45713	0.57911	0.47400	0.32073	0.25272	0.44978	0.39849	0.45876	0.90715	1.21144	0.58145	0.52492	0.62477

n.e.c.—Not elsewhere classified.
M&E—Machinery and equipment.

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SPRING, 1966

Reconstructed 1959 Soviet Input-Output Table

b. Direct Input Coefficients, Technology Matrix

(Material coefficients in rubles per ruble of gross output, labor input coefficients in man-years per 1000 rubles of gross output)

Producing sector \ Using sector	1 Ferrous ores	2 Ferrous metals	3 Nonferrous ores	4 Nonferrous metals	5 Coking coal	6 Metal products	7 Coal	8 Oil	9 Gas	10 Other fuels	11 Electrical power	12 Electrical & power M&E	13 Tools & instruments	14 General machinery	15 Transportation M&E	16 Automobiles	17 Agricultural M&E	18 Machinery n.e.c.	19 Metal working	20 Repair of machinery	21 Abrasives	22 Mineral & basic chemicals	23 Synthetics, paints	24 Rubber products	25 Lumber & woodworking	26 Paper	27 Construction materials	28 Glass	29 Textiles	30 Apparel and footwear	31 Food	32 Industry n.e.c.	33 Construction	34 Agriculture	35 Forestry	36 Transport. and comm.	37 Trade & distribution	38 Products n.e.c.
1 Ferrous ores	0.00160	0.04505	0.00000	0.01235	0.00000	0.02868	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01605	0.00125	0.00000	0.00000	0.00000	0.00000	0.00064	0.00707	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2 Ferrous metals	0.01530	0.13202	0.01921	0.00000	0.00118	0.41641	0.00451	0.00148	0.00226	0.00545	0.00101	0.14947	0.04357	0.14904	0.09592	0.07147	0.12041	0.00978	0.19496	0.09155	0.01364	0.00516	0.00382	0.00185	0.00164	0.00426	0.02733	0.00570	0.00030	0.00015	0.00120	0.01266	0.04675	0.00010	0.00000	0.00566	0.00506	0.00060
3 Nonferrous ores	0.00000	0.00000	0.00097	0.20846	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02006	0.00221	0.00000	0.00000	0.00000	0.00000	0.00312	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4 Nonferrous metals	0.00000	0.08543	0.00000	0.14399	0.00000	0.00594	0.00044	0.00018	0.00000	0.00091	0.00025	0.07322	0.11957	0.03341	0.02393	0.04756	0.01300	0.00978	0.02891	0.03165	0.02006	0.00737	0.02646	0.00195	0.00027	0.00150	0.00648	0.00456	0.00010	0.00015	0.00032	0.00542	0.00074	0.00001	0.00000	0.00205	0.00143	0.00007
5 Coking coal	0.01067	0.11360	0.00000	0.04023	0.06754	0.01711	0.00005	0.00101	0.00038	0.00000	0.00000	0.00120	0.00070	0.00493	0.00124	0.00214	0.00383	0.00037	0.01054	0.00336	0.00963	0.03183	0.01042	0.00010	0.00410	0.00008	0.00181	0.00011	0.00002	0.00001	0.00002	0.00000	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000
6 Metal products	0.00676	0.01388	0.00387	0.00595	0.00059	0.03206	0.00207	0.00037	0.00038	0.00291	0.00062	0.00787	0.00782	0.01340	0.00706	0.01209	0.01370	0.00272	0.01361	0.01344	0.00401	0.00405	0.00068	0.00370	0.00502	0.00150	0.00586	0.01720	0.00037	0.00074	0.00021	0.00000	0.00797	0.00023	0.00065	0.00338	0.00185	0.00083
7 Coal	0.02473	0.08124	0.01305	0.00890	0.71658	0.01844	0.13183	0.00001	0.03947	0.01236	0.22285	0.00759	0.00192	0.00655	0.00886	0.00483	0.00370	0.00178	0.00491	0.01341	0.02488	0.01887	0.00985	0.00240	0.00260	0.03717	0.03438	0.02792	0.00206	0.00098	0.00316	0.00376	0.00170	0.00022	0.00000	0.07134	0.00604	0.00097
8 Oil	0.00552	0.01570	0.02731	0.01872	0.00118	0.01455	0.00124	0.15911	0.01541	0.02127	0.06865	0.00971	0.00294	0.01065	0.00796	0.00824	0.00401	0.00254	0.00377	0.01592	0.03531	0.01113	0.02635	0.00720	0.02548	0.01026	0.02033	0.02325	0.00079	0.00071	0.00337	0.00378	0.01255	0.01966	0.01656	0.08543	0.00287	0.00117
9 Gas	0.00018	0.00037	0.00060	0.00044	0.00067	0.00143	0.00002	0.00021	0.00038	0.00055	0.01913	0.00016	0.00012	0.00016	0.00025	0.00019	0.00029	0.00006	0.00014	0.00024	0.00080	0.00044	0.00359	0.00010	0.00004	0.00008	0.00174	0.00103	0.00005	0.00002	0.00008	0.00009	0.00033	0.00000	0.00000	0.00000	0.00000	0.00000
10 Other fuels	0.00000	0.00003	0.00012	0.00003	0.01346	0.00010	0.00002	0.00003	0.03985	0.03782	0.06479	0.00040	0.00007	0.00344	0.00139	0.00016	0.00016	0.00037	0.00097	0.00037	0.00000	0.00029	0.00034	0.00010	0.00249	0.00758	0.00381	0.01584	0.00083	0.00046	0.00026	0.00034	0.00029	0.00001	0.00000	0.00000	0.00000	0.00000
11 Electrical power	0.04465	0.01436	0.01486	0.05261	0.02604	0.03124	0.02175	0.02593	0.00752	0.04055	0.00123	0.01818	0.00772	0.01744	0.01114	0.00652	0.01671	0.00671	0.00908	0.01579	0.07143	0.04915	0.02128	0.01340	0.00433	0.03370	0.03064	0.01527	0.00438	0.00278	0.00193	0.01098	0.00687	0.00165	0.00000	0.01334	0.00370	0.00087
12 Electrical & power M&E	0.00267	0.00108	0.00254	0.00060	0.00044	0.00072	0.00096	0.00016	0.00075	0.00364	0.00224	0.07642	0.00730	0.04818	0.11363	0.00584	0.00802	0.05455	0.00563	0.01547	0.00161	0.00140	0.00083	0.00025	0.00062	0.00079	0.00067	0.00103	0.00015	0.00014	0.00010	0.00622	0.00436	0.00075	0.00000	0.00041	0.00130	0.00037
13 Tools & instruments	0.00587	0.00240	0.00568	0.00133	0.00037	0.00789	0.00426	0.00048	0.00113	0.00855	0.00089	0.05080	0.03195	0.02543	0.01672	0.01216	0.02049	0.03870	0.00439	0.02352	0.00482	0.00258	0.00079	0.00140	0.00197	0.00189	0.00322	0.00182	0.00023	0.00019	0.00018	0.00823	0.01887	0.00022	0.00000	0.00258	0.00084	0.00003
14 General machinery	0.01672	0.00679	0.01607	0.00381	0.00037	0.00440	0.00895	0.00333	0.00150	0.01418	0.00008	0.00092	0.00047	0.04550	0.00592	0.00036	0.00148	0.00227	0.00069	0.00552	0.00080	0.00516	0.00127	0.00085	0.00192	0.00497	0.00498	0.00125	0.00159	0.00055	0.00042	0.00429	0.00288	0.00000	0.00000	0.00022	0.00432	0.00000
15 Transportation M&E	0.00053	0.00025	0.00060	0.00013	0.00000	0.00020	0.00009	0.00000	0.00000	0.00273	0.00000	0.00000	0.00010	0.00786	0.04537	0.00000	0.00000	0.00139	0.00000	0.01739	0.00000	0.00007	0.00002	0.00000	0.00024	0.00000	0.00001	0.00000	0.00000	0.00000	0.00001	0.00208	0.00022	0.00007	0.00000	0.01352	0.00000	0.00000
16 Automobiles	0.00142	0.00059	0.00133	0.00034	0.00000	0.00102	0.00008	0.00016	0.00038	0.00127	0.00014	0.00124	0.00202	0.02891	0.00428	0.10217	0.00469	0.01696	0.00128	0.06720	0.00080	0.00140	0.00015	0.00080	0.00614	0.00039	0.00286	0.00046	0.00006	0.00003	0.00007	0.00694	0.00242	0.00036	0.00000	0.01837	0.00000	0.00023
17 Agricultural M&E	0.00053	0.00020	0.00048	0.00013	0.00000	0.00010	0.00011	0.00025	0.00000	0.00836	0.00003	0.00739	0.00000	0.02012	0.00179	0.00003	0.03951	0.01182	0.00076	0.05445	0.00000	0.00022	0.00002	0.00000	0.00520	0.00008	0.00099	0.00011	0.00002	0.00000	0.00001	0.00501	0.00155	0.00297	0.01136	0.00013	0.00000	0.00000
18 Machinery n.e.c.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01384	0.00418	0.00376	0.03709	0.00587	0.01011	0.00163	0.02096	0.02373	0.00308	0.00576	0.02667	0.00000	0.01333	0.00000	0.00796	0.00225	0.00240	0.00000	0.00000	0.01269	0.00000	0.00000	0.00000	0.00142	0.01103	0.00784	0.00776	0.00000	0.00613	0.01203	0.00000
19 Metal working	0.00231	0.00090	0.00218	0.00050	0.00015	0.00154	0.00158	0.00010	0.00000	0.00091	0.00031	0.00827	0.00072	0.00774	0.02095	0.00477	0.00152	0.00000	0.01610	0.01165	0.00321	0.00228	0.00248	0.00195	0.00835	0.00237	0.00214	0.01276	0.00081	0.00162	0.00099	0.01136	0.04140	0.00293	0.01006	0.00000	0.00033	0.00000
20 Repair of machinery	0.03896	0.01572	0.03722	0.00885	0.00244	0.00502	0.00033	0.00482	0.00752	0.00236	0.01667	0.00260	0.00173	0.00289	0.00303	0.00208	0.00099	0.00000	0.00107	0.00000	0.02247	0.00781	0.00707	0.00160	0.00427	0.00268	0.01225	0.02792	0.00056	0.00031	0.00397	0.01170	0.00000	0.01922	0.00000	0.00767	0.00000	0.00000
21 Abrasives	0.00213	0.00049	0.00205	0.00029	0.00000	0.00133	0.00005	0.00001	0.00000	0.00018	0.00003	0.01890	0.00207	0.00121	0.00194	0.00104	0.00140	0.00000	0.00076	0.00083	0.06902	0.00007	0.00023	0.00005	0.00046	0.00008	0.00014	0.00171	0.00001	0.00009	0.00000	0.00000	0.00033	0.00010	0.00000	0.00000	0.00013	0.00000
22 Mineral & basic chemls	0.01139	0.00603	0.01100	0.00339	0.01147	0.00338	0.00066	0.00615	0.00150	0.00418	0.00109	0.00619	0.00151	0.00236	0.00294	0.00208	0.00128	0.00155	0.00221	0.00269	0.02970	0.11172	0.04373	0.00220	0.00136	0.01452	0.00064	0.00239	0.00001	0.00065	0.00048	0.01452	0.00061	0.00665	0.00877	0.00082	0.00066	0.00003
23 Synthetics, paints	0.00445	0.00227	0.00411	0.00128	0.00037	0.00236	0.00027	0.00240	0.00451	0.00127	0.00039	0.02894	0.02344	0.00947	0.01284	0.01174	0.00737	0.00951	0.01216	0.01717	0.00241	0.02690	0.20692	0.30950	0.00721	0.00268	0.00149	0.01265	0.01302	0.01189	0.00075	0.04334	0.00698	0.00104	0.00000	0.00459	0.00106	0.00393
24 Rubber products	0.00445	0.00236	0.00423	0.00133	0.00052	0.00174	0.00422	0.00018	0.00038	0.00545	0.00022	0.00855	0.00377	0.01966	0.00816	0.12185	0.03794	0.00761	0.00173	0.00635	0.00161	0.00162	0.00274	0.10485	0.00557	0.00103	0.00281	0.00103	0.00112	0.00160	0.00013	0.02195	0.00237	0.00024	0.00000	0.03197	0.00479	0.00097
25 Lumber & woodworking	0.02544	0.00597	0.02417	0.00337	0.00067	0.01567	0.06214	0.00076	0.00188	0.02473	0.00081	0.01127	0.00812	0.01354	0.02821	0.00872	0.01387	0.00693	0.00518	0.02861	0.00401	0.01098	0.01714	0.00855	0.24565	0.25620	0.01673	0.03579	0.00177	0.00423	0.00501	0.01168	0.10213	0.00212	0.00357	0.01520	0.01804	0.00067
26 Paper	0.00107	0.00025	0.00109	0.00013	0.00007	0.01004	0.00008	0.00012	0.00000	0.00018	0.00006	0.00460	0.00237	0.00085	0.00050	0.00120	0.00066	0.00090	0.00069	0.00104	0.00321	0.00575	0.00970	0.00055	0.00048	0.06322	0.00359	0.00490	0.00027	0.00099	0.00128	0.01725	0.00112	0.00000	0.00130	0.00028	0.05121	0.05450
27 Construction materials	0.00409	0.00097	0.00399	0.00055	0.00015	0.00164	0.00186	0.00066	0.00075	0.00145	0.00050	0.00224	0.00059	0.00172	0.00731	0.00084	0.00082	0.00000	0.00173	0.00800	0.00401	0.00258	0.00076	0.00045	0.00102	0.00537	0.17434	0.00798	0.00026	0.00021	0.00044	0.00000	0.18359	0.00030	0.00292	0.00537	0.00002	0.00003
28 Glass	0.00089	0.00019	0.00073	0.00010	0.00007	0.00020	0.00008	0.00004	0.00000	0.00018	0.00011	0.00540	0.00311	0.00041	0.00174	0.00447	0.00029	0.00000	0.00159	0.00168	0.00080	0.00088	0.00583	0.00010	0.00359	0.00032	0.00012	0.01482	0.00003	0.00005	0.00085	0.00000	0.01093	0.00010	0.00000	0.00052	0.00000	0.00000
29 Textiles	0.00249	0.00134	0.00230	0.00076	0.00022	0.02336	0.00030	0.00015	0.00038	0.00109	0.00028	0.01219	0.00844	0.00225	0.00796	0.00584	0.00580	0.00685	0.00221	0.00736	0.09470	0.00575	0.01229	0.19755	0.01841	0.00663	0.00134	0.00661	0.24151	0.39897	0.00148	0.00170	0.00102	0.00086	0.00000	0.00658	0.03508	0.00773
30 Apparel and footwear	0.01423	0.00796	0.01366	0.00449	0.00266	0.01629	0.02073	0.00134	0.00301	0.02782	0.00266	0.00552	0.00479	0.00912	0.00821	0.01141	0.00745	0.00000	0.00691	0.00731	0.00883	0.01489	0.00477	0.00255	0.01397	0.00481	0.00583	0.01037	0.00098	0.12310	0.00188	0.00000	0.01834	0.00187	0.00065	0.00629	0.00784	0.00037
31 Food	0.00178	0.00096	0.00157	0.00055	0.00044	0.00041	0.00027	0.00028	0.00038	0.00055	0.00042	0.00188	0.00079	0.00087	0.00109	0.00068	0.00045	0.00000	0.00062	0.00088	0.02167	0.01489	0.08606	0.00350	0.00281	0.00103	0.00107	0.00091	0.00080	0.03426	0.23124	0.14822	0.00292	0.02958	0.00000	0.00000	0.00099	0.00000
32 Industry n.e.c.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00911	0.00511	0.00871	0.00751	0.00820	0.00745	0.00344	0.00000	0.00000	0.00000	0.00391	0.00284	0.00375	0.00000	0.00000	0.01271	0.00000	0.00097	0.00143	0.00000	0.00000	0.00000	0.00240	0.00000	0.00000	0.00000	0.00000
33 Construction	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
34 Agriculture	0.00000	0.00009	0.00000	0.00021	0.00000	0.00031	0.00041	0.00001	0.00000	0.00036	0.00000	0.00008	0.00002	0.00007	0.00025	0.00000	0.00000	0.00000	0.00003	0.00005	0.00000	0.00022	0.00244	0.00000	0.00295	0.00087	0.00008	0.00034	0.15488	0.02803	0.28490	0.03757	0.00038	0.23246	0.01461	0.00169	0.00000	0.00000
35 Forestry	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01294	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00228	0.00000	0.02013	0.00000	0.00000	0.00527
36 Transport. and comm.	0.14232	0.06182	0.04254	0.03679	0.03277	0.05870	0.73949	0.17665	0.00075	0.12091	0.00134	0.02346	0.01086	0.04472	0.00876	0.03781	0.05424	0.00450	0.08225	0.00453	0.03612	0.37878	0.00745	0.02790	0.14739	0.05754	0.23632	0.09802	0.01108	0.00912	0.02097	0.00792	0.00133	0.01425	0.01623	0.00437	0.01025	0.02667
37 Trade & distribution	0.03380	0.03391	0.03299	0.03384	0.00000	0.03145	0.02291	0.10157	0.05414	0.00273	0.00232	0.01467	0.01567	0.00431	0.00000	0.01676	0.02025	0.01508	0.03554	0.00000	0.00000	0.01599	0.01042	0.00865	0.03665	0.07064	0.04637	0.10087	0.02725	0.04021	0.06370	0.13068	0.00000	0.05341	0.00000	0.00000	0.00000	0.00390
38 Products n.e.c.	0.00000	0.01371	0.00000	0.02313	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00192	0.00098	0.00392	0.00423	0.00091	0.00667	0.00157	0.00642	0.00197	0.00000	0.00000	0.01173	0.00535	0.00000	0.06164	0.00705	0.01220	0.00000	0.00559	0.00140	0.05280	0.00927	0.00011	0.00000	0.00000	0.00000	0.00000
39 Labor input coefficients	0.26300	0.10786	0.20000	0.08591	0.03250	0.10294	0.19645	0.02633	0.05330	0.44594	0.11336	0.18904	0.14515	0.19706	0.17552	0.11247	0.17504	0.24276	0.23395	0.32951	0.22264	0.09735	0.09153	0.05000	0.25857	0.11571	0.27224	0.24419	0.07079	0.01097	0.04377	0.10902	0.21260	0.61869	1.14302	0.47085	0.45504	0.56967

n.e.c.—Not elsewhere classified.
M&E—Machinery and equipment.

VLADIMIR G. TREML,
RESEARCH ANALYSIS CORPORATION,
SPRING, 1966

63-591 O - 66 - pt. II-A (Face p. 269) No. 2

Reconstructed 1959 Soviet Input-Output Table

a. Interindustry Transactions Matrix

(Product in millions of current rubles, employment in thousands of man years)

Producing sector \ Using sector	Ferrous ores	Ferrous metals	Nonferrous ores	Nonferrous metals	Coking coal	Metal products	Coal	Oil	Gas	Other fuels	Electrical power	Electrical & power M&E	Tools & instruments	General machinery	Transportation M&E	Automobiles	Agricultural M&E	Machinery n.e.c.	Metal working	Repair of machinery	Abrasives	Mineral & basic chemls	Synthetics, paints	Rubber products	Lumber & woodworking	Paper	Construction materials	Glass	Textiles	Apparel and footwear	Food	Industry n.e.c.	Construction	Agriculture	Forestry	Transport. and comm.	Trade & distribution	Products n.e.c.	Total interindustry use	Private consumption	Public consumption	Gross investment	Exports	Total final demand	Total gross output
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1 Ferrous ores	C.9	291.5	0.	47.3	0.	28.0	0.	0.	0.	0.	0.	0.	0.	0.	C.	C.	0.	C.	C.	0.	2.0	1.7	0.	0.	0.	0.	4.7	6.2	C.	C.	0.	0.	0.	0.	0.	0.	0.	0.	382.3	0.	0.	-21.1	200.9	179.8	562.1
2 Ferrous metals	8.6	854.2	15.9	0.	1.6	406.5	28.8	9.9	0.6	3.0	3.6	374.0	176.6	650.6	192.8	220.4	292.6	50.0	564.4	343.3	1.7	7.0	18.0	3.7	18.1	5.4	199.6	5.0	7.8	2.7	69.1	70.0	1365.0	5.5	0.	63.7	57.5	1.8	6099.0	2.1	20.0	-183.4	532.3	371.0	6470.0
3 Nonferrous ores	C.	C.	0.8	798.4	0.	0.	C.	0.	0.	0.	0.	0.	0.	0.	C.	0.	C.	0.	0.	0.	2.5	3.0	0.	0.	0.	0.	22.8	0.	C.	C.	0.	0.	0.	0.	0.	0.	0.	0.	827.5	0.	0.	-15.2	15.2	0.	827.5
4 Nonferrous metals	0.	552.7	0.	551.5	0.	5.8	2.8	1.2	C.	0.5	0.9	183.2	484.6	145.8	48.1	146.6	31.6	50.0	83.7	118.7	2.5	10.0	124.7	3.9	3.0	1.9	47.3	4.0	2.5	2.7	18.4	30.0	21.7	0.3	0.	23.1	16.2	0.2	2720.1	2.1	292.3	619.8	195.7	1109.9	3830.0
5 Coking coal	6.C	735.C	C.	154.1	91.3	16.7	C.3	6.8	0.1	0.	0.	3.0	0.8	21.5	2.5	6.6	9.3	1.9	30.5	12.6	1.2	43.2	49.1	C.2	45.2	0.1	13.2	0.1	C.5	C.1	C.5	0.	0.	0.	0.	0.2	0.	0.	1253.0	0.	0.	68.3	30.4	98.7	1351.7
6 Metal products	3.8	89.8	3.2	22.8	0.8	31.3	13.2	2.5	C.1	1.6	2.2	19.7	31.7	58.5	14.2	37.3	26.C	13.9	39.4	50.4	C.5	5.5	3.2	7.4	55.4	1.9	42.8	10.7	9.5	12.5	12.4	C.	232.6	12.1	0.2	38.0	21.0	2.5	931.0	12.8	40.4	-18.0	10.0	45.2	976.2
7 Coal	13.9	525.6	1C.8	34.1	968.6	18.0	841.2	0.1	10.5	6.8	796.9	19.0	7.8	28.6	17.8	14.9	9.C	9.1	14.2	50.3	3.1	25.6	46.4	4.8	28.7	47.1	251.1	24.5	53.C	17.1	182.5	20.8	49.5	11.7	0.	803.0	68.6	2.9	5037.6	146.3	542.2	426.1	228.8	1343.4	6381.0
8 Oil	3.1	101.6	22.6	71.7	1.6	14.2	7.9	1066.5	4.1	11.7	245.5	24.3	11.9	46.5	16.C	25.4	14.6	13.0	1C.9	59.7	4.4	15.1	124.2	14.4	281.1	13.0	148.5	20.4	2C.4	12.4	194.7	2C.9	366.5	1051.7	5.1	961.6	32.6	3.5	5C63.3	103.2	360.7	609.4	566.4	1639.7	6703.0
9 Gas	C.1	2.4	C.5	1.7	C.9	1.4	0.1	1.4	0.1	C.3	68.4	0.4	0.5	0.7	C.5	C.6	C.7	C.3	C.4	0.9	0.1	0.6	16.9	0.2	0.4	0.1	12.7	0.9	1.2	C.3	4.4	0.5	9.7	0.	0.	0.	0.	0.	130.3	49.8	36.0	48.2	1.7	135.7	266.0
10 Other fuels	C.	C.2	C.1	0.1	18.2	0.1	C.1	0.2	10.6	20.8	231.7	1.0	0.3	15.0	2.8	C.5	0.4	1.9	2.8	1.4	C.	0.4	1.6	C.2	27.5	9.6	27.8	13.9	21.3	8.C	15.1	1.9	8.5	0.3	0.	0.	0.	0.	444.3	0.	60.2	45.5	0.	105.7	550.0
11 Electrical power	25.1	92.9	12.3	201.5	35.2	30.5	138.8	173.8	2.0	22.3	4.4	45.5	31.3	76.1	22.4	20.1	4C.6	34.3	26.3	59.2	8.9	66.7	100.3	26.8	47.8	42.7	223.8	13.4	112.5	48.6	111.5	60.7	200.6	88.3	0.	150.2	42.1	2.6	2442.1	635.5	397.3	101.1	0.	1133.9	3576.0
12 Electrical & power M&E	1.5	7.C	2.1	2.3	0.6	0.7	6.1	1.1	C.2	2.0	8.0	191.2	29.6	210.3	228.4	18.C	19.5	278.8	16.3	58.0	0.2	1.9	3.9	C.5	6.8	1.0	4.9	0.9	3.9	2.4	5.6	34.4	127.3	38.8	0.	4.6	14.8	1.1	1334.7	329.3	57.0	727.6	53.5	1167.4	2502.1
13 Tools & instruments	3.3	15.5	4.7	5.1	C.5	7.7	27.2	3.2	0.3	4.7	3.2	127.1	129.5	111.0	33.6	37.5	49.8	197.8	12.7	88.2	0.6	3.5	3.7	2.8	21.7	2.4	23.5	1.6	5.9	3.3	10.3	45.5	551.1	11.8	0.	29.0	9.6	0.1	1589.0	605.1	56.9	1377.9	424.1	2464.0	4053.0
14 General machinery	9.4	43.9	13.3	14.6	0.5	4.3	57.1	22.3	C.4	7.8	0.3	2.3	1.9	198.6	11.9	1.1	3.6	11.6	2.0	20.7	C.1	7.0	6.C	1.7	21.2	6.3	36.4	1.1	40.8	9.6	24.C	23.7	84.0	0.	0.	2.5	49.1	0.	741.1	234.0	0.2	3012.8	376.5	3623.5	4364.6
15 Transportation M&E	C.3	1.6	C.5	C.5	0.	0.2	0.6	0.	0.	1.5	0.	0.	0.4	12.5	91.2	C.	0.	7.1	0.	65.2	0.	0.1	0.1	C.	2.6	C.	0.1	0.	C.	0.	0.4	11.5	6.4	3.5	0.	152.2	0.	0.	358.5	0.	35.8	1525.5	90.2	1651.5	2010.0
16 Automobiles	C.8	3.8	1.1	1.3	0.	1.0	C.5	1.1	0.1	0.7	0.5	3.1	8.2	126.2	8.6	315.1	11.4	86.7	3.7	252.0	C.1	1.9	C.7	1.6	67.7	0.5	20.9	0.4	1.5	0.6	4.1	38.4	70.6	19.0	0.	206.8	0.	0.7	1261.4	555.7	74.9	1030.3	161.7	1822.6	3084.0
17 Agricultural M&E	C.3	1.3	C.4	0.5	0.	0.1	0.7	1.7	0.	4.6	0.1	18.5	0.	87.8	3.6	C.1	217.5	60.4	2.2	204.2	0.	0.3	0.1	C.	57.4	0.1	7.2	0.1	0.4	0.	0.6	27.7	45.4	159.0	3.5	1.5	0.	0.	907.3	0.	0.	1421.3	101.4	1522.7	2430.0
18 Machinery n.e.c.	C.	C.	0.	C.	0.	0.	88.3	28.0	1.0	20.4	21.0	25.3	6.6	91.5	47.7	9.5	14.C	136.3	C.	50.0	C.	10.8	1C.6	4.8	C.	0.	92.7	0.	0.	0.	82.C	61.0	228.8	414.9	0.	69.0	136.7	0.	1650.9	578.3	166.5	2700.9	14.7	3460.4	5111.3
19 Metal working	1.2	5.8	1.8	1.9	0.2	1.5	10.1	0.7	0.	0.5	1.1	20.7	2.9	33.8	42.1	14.7	3.7	0.	46.6	43.7	0.4	3.1	11.7	3.9	92.1	3.0	15.6	11.2	20.8	28.3	57.3	62.8	1208.9	156.6	3.1	0.	3.7	0.	1915.6	859.1	188.4	-68.1	0.	979.4	2895.0
20 Repair of machinery	21.9	1C1.7	30.8	33.9	3.3	4.9	2.1	32.3	2.0	1.3	59.6	6.5	7.0	12.6	6.1	6.4	2.4	C.	3.1	0.	2.8	10.6	33.3	3.2	47.1	3.4	89.5	24.5	14.4	5.5	229.2	64.7	0.	1028.1	0.	86.3	0.	0.	1980.5	0.	19.8	1749.7	0.	1769.5	3750.0
21 Abrasives	1.2	3.2	1.7	1.1	0.	1.3	0.3	0.1	0.	0.1	0.1	47.3	8.4	5.3	3.9	3.2	3.4	0.	2.2	3.1	8.6	0.1	1.1	0.1	5.1	0.1	1.0	1.5	C.2	1.5	0.2	0.	9.5	5.2	0.	0.	1.5	0.	121.6	0.	0.	2.5	0.5	3.0	124.6
22 Mineral & basic chemls	6.4	39.C	9.1	13.0	15.5	3.3	4.2	41.2	0.4	2.3	3.9	15.5	6.1	10.3	5.9	6.4	3.1	7.9	6.4	10.1	3.7	151.6	206.1	4.4	15.0	18.4	4.7	2.1	0.2	11.3	27.7	80.3	17.7	355.6	2.7	9.2	7.5	0.1	1128.3	42.4	43.4	31.5	111.4	228.7	1357.0
23 Synthetics, paints	2.5	14.7	3.4	4.9	0.5	2.3	1.7	16.1	1.2	0.7	1.4	72.4	95.0	41.1	25.8	36.2	17.9	48.6	35.2	64.4	C.3	36.5	975.2	619.C	79.6	3.4	10.9	11.1	334.7	208.C	43.3	239.7	2C3.8	55.4	0.	51.7	12.0	11.8	3382.4	357.1	402.1	518.5	52.9	1330.6	4713.0
24 Rubber products	2.5	15.3	3.5	5.1	C.7	1.7	26.9	1.2	0.1	3.0	0.8	21.4	15.3	85.8	16.4	375.8	92.2	38.9	5.0	23.8	0.2	2.2	12.9	209.7	61.4	1.3	20.5	0.9	28.9	28.C	7.3	121.4	69.3	12.6	0.	359.9	54.4	2.9	1729.2	34.5	132.0	92.7	11.6	270.8	2000.0
25 Lumber & woodworking	14.3	38.6	20.C	12.9	0.9	15.3	396.5	5.1	0.5	13.6	2.9	28.2	32.9	59.1	56.7	26.9	33.7	35.4	15.C	107.3	0.5	14.9	80.8	17.1	2710.3	324.6	122.2	31.4	45.5	74.C	289.3	64.6	2982.3	113.5	1.1	171.1	205.0	2.0	8166.0	1271.6	424.9	920.9	249.6	2867.0	11033.0
26 Paper	C.6	1.6	0.5	C.5	0.1	9.8	0.5	0.8	0.	0.1	C.2	11.5	9.6	3.7	1.C	3.7	1.6	4.6	2.C	3.9	C.4	7.8	45.7	1.1	5.3	80.1	26.2	4.3	6.9	17.2	73.8	95.4	32.6	0.1	0.4	3.1	582.0	163.5	1202.7	0.	81.2	-33.2	16.3	64.3	1267.0
27 Construction materials	2.3	6.2	3.3	2.1	0.2	1.6	11.9	4.4	0.2	0.8	1.8	5.6	2.4	7.5	14.7	2.6	2.C	C.	5.0	30.0	0.5	3.5	3.6	0.9	11.3	6.8	1273.4	7.0	6.8	3.7	25.3	0.	5360.9	16.2	0.9	60.5	0.2	0.1	6886.3	122.9	274.6	9.8	10.4	417.7	7304.0
28 Glass	C.5	1.2	C.6	0.4	0.1	0.2	0.5	0.3	0.	0.1	0.4	13.5	12.6	1.8	3.5	13.8	C.7	C.	4.6	6.3	C.1	1.2	27.5	0.2	39.6	0.4	0.9	13.0	0.7	0.9	49.4	0.	319.3	5.1	0.	5.9	0.	0.	525.3	333.7	17.6	-2.1	2.9	352.1	877.4
29 Textiles	1.4	8.7	1.9	2.9	0.3	22.8	1.9	1.0	0.1	0.6	1.0	30.5	34.2	9.8	16.0	18.C	14.1	35.0	6.4	27.6	11.8	7.8	57.9	395.1	203.1	8.4	9.8	5.8	6206.7	6981.9	85.6	9.4	29.9	46.2	0.	74.1	398.6	23.2	14789.5	9287.0	337.2	1115.4	170.9	10910.5	25700.0
30 Apparel and footwear	8.C	51.5	11.3	17.2	3.6	15.9	132.3	9.0	C.8	15.3	9.5	13.8	19.4	39.8	16.5	35.2	18.1	0.	2C.0	27.4	1.1	20.2	22.5	5.1	154.1	6.1	42.6	9.1	25.2	2154.3	108.8	0.	535.5	99.8	0.2	70.8	89.1	1.1	3810.2	10205.9	439.0	2988.1	56.8	13689.8	17500.0
31 Food	1.C	6.2	1.3	2.1	0.6	0.4	1.7	1.9	0.1	0.3	1.5	4.7	3.2	3.8	2.2	2.1	1.1	0.	1.8	3.3	2.7	20.2	405.6	7.C	31.0	1.3	7.8	0.8	20.5	599.6	13365.8	819.7	85.2	1582.4	0.	0.	11.3	0.	17000.2	35575.0	1214.4	3138.1	872.3	40799.8	57800.0
32 Industry n.e.c.	C.	C.	C.	0.	0.	0.	0.	0.	0.	0.	0.	22.8	20.7	38.0	15.1	25.3	18.1	17.6	C.	0.	C.	5.3	13.4	7.5	C.	0.	92.8	0.	25.0	25.C	0.	0.	0.	128.3	0.	0.	0.	0.	454.9	4805.1	610.7	-381.3	41.0	5075.5	5530.4
33 Construction	C.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	C.	0.	0.	C.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	29200.0	0.	29200.0	29200.0
34 Agriculture	C.	0.6	0.	0.8	0.	0.3	2.6	0.1	0.	0.2	0.	0.2	0.1	0.3	C.5	0.	0.	0.	0.1	0.2	0.	0.3	11.5	C.	32.6	1.1	0.6	0.3	3980.3	490.5	16467.3	207.8	11.2	12436.5	4.5	19.0	0.	0.	33669.5	17096.9	515.7	1557.9	660.0	19830.5	53500.0
35 Forestry	C.	0.	0.	C.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	C.	0.	142.8	0.	0.	0.	0.	C.	0.	C.	66.5	0.	6.2	0.	0.	15.8	231.3	0.	0.	76.7	0.	76.7	308.0
36 Transport. and comm.	8C.C	40C.C	35.2	140.9	44.3	57.3	1528.2	1184.1	C.2	66.5	4.8	58.7	44.0	195.2	17.6	116.6	131.8	23.0	238.1	17.0	4.5	514.0	35.1	55.8	1626.1	72.9	1726.1	86.0	284.7	159.6	1212.3	43.8	38.9	762.2	5.0	49.2	116.5	80.0	11256.2	0.	0.	0.	0.	0.0	11256.2
37 Trade & distribution	19.C	219.4	27.3	129.6	0.	30.7	146.2	680.8	14.4	1.5	8.3	36.7	63.5	18.8	0.	51.7	49.2	77.1	1C2.9	0.	0.	21.7	49.1	17.3	404.4	89.5	338.7	88.5	7C0.3	703.7	3681.6	722.7	0.	2857.6	C.	0.	0.	11.7	11363.9	0.	0.	0.	0.	0.0	11363.9
38 Products n.e.c.	C.	88.7	0.	88.6	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.8	3.9	17.1	8.5	2.8	16.2	8.0	18.6	7.4	C.	0.	55.3	10.7	C.	78.1	51.5	10.7	0.	97.9	80.7	292.0	270.7	6.0	0.	0.	0.	1218.2	1929.6	157.9	-309.9	4.2	1781.8	3000.0
39 Total purchases	24C.C	4321.5	240.4	2365.4	1190.1	735.8	3481.3	3298.9	50.1	215.6	1484.0	1452.4	1302.9	2465.0	994.6	1595.1	1149.9	1249.2	1322.5	1810.3	65.5	1025.3	2557.8	1431.1	6345.5	831.0	5014.8	411.4	11983.C	11711.7	36540.9	3271.3	146C9.9	21484.3	32.9	3466.2	1930.0	327.6	154005.2	85175.0	6999.3	54084.2	5264.3	151522.8	305528.0
40 Depreciation	57.8	296.0	73.0	167.6	45.8	32.4	307.2	300.0	17.4	44.5	500.1	95.0	83.7	157.6	68.4	57.1	67.8	166.7	68.7	125.5	3.1	44.1	148.4	13.6	302.0	40.1	316.6	21.3	110.0	110.0	443.1	125.2	579.0	2100.0	0.	1195.0	434.0	266.0	8983.8	2825.5	2094.5	0.	0.	4920.0	13903.8
41 Labor income	188.3	1073.6	238.4	754.2	103.1	200.8	3035.6	287.7	16.3	260.9	426.6	759.9	669.4	1260.6	547.1	442.3	426.3	1436.8	549.6	1004.2	32.1	195.8	593.7	176.5	3020.5	200.6	1794.3	232.2	923.8	1410.3	2531.7	701.3	7021.9	23800.0	275.1	4853.0	3827.6	1563.7	66835.8						
42 Other net income	76.0	522.1	-44.9	378.3	12.7	7.2	-526.2	2675.4	182.2	29.0	1165.3	99.7	1863.4	-115.5	-75.6	939.6	775.5	2234.9	948.9	810.0	22.3	65.8	1151.6	361.3	1236.4	181.2	141.2	204.5	11454.1	1987.7	16893.7	1383.5	6989.2	4815.7	0.	1742.0	5172.3	842.7	66603:2						
43 National income	264.3	1595.7	193.5	1132.5	115.8	208.0	2509.4	2963.1	198.5	289.9	1591.9	859.6	2532.8	1145.1	471.5	1381.9	1201.8	3671.7	1498.5	1814.2	54.4	261.6	1745.3	537.8	4256.9	381.8	1935.5	436.7	12377.9	3398.0	19425.4	2084.8	14011.1	28615.7	275.1	6595.0	8999.9	2406.4	133439.0						
44 Imports	0.	256.8	320.6	164.5	0.	0.	83.1	141.0	0.	0.	0.	95.1	133.6	596.9	475.5	49.9	10.5	23.7	5.3	0.	1.6	26.0	261.5	17.5	128.6	14.1	37.1	8.0	1229.1	2280.3	1390.6	49.1	0.	1300.0	0.	0.	0.	0.	9100.0						
45 Total outlays	562.1	6470.0	827.5	3830.0	1351.7	976.2	6381.0	6703.0	266.0	550.0	3576.0	2502.1	4053.0	4364.6	2010.0	3084.0	2430.0	5111.3	2895.0	3750.0	124.6	1357.0	4713.0	2000.0	11033.0	1267.0	7304.0	877.4	25700.0	17500.0	57800.0	5530.4	29200.0	53500.0	308.0	11256.2	11363.9	3000.0	305528.0						
46 Employment	147.7	697.9	130.7	328.9	43.9	100.5	1253.6	176.5	14.2	245.3	405.4	473.0	588.3	860.1	353.0	347.0	425.0	1240.8	677.3	1236.0	27.7	132.1	431.1	100.0	2852.8	147.0	1623.3	214.3	1820.0	1920.0	2530.0	600.0	6208.0	33100.0	352.0	5300.0	5171.0	1709.0	73983.4						

n.e.c.—Not elsewhere classified.
M&E—Machinery and equipment.

VLADIMIR G. TREML,
RESEARCH ANALYSIS CORPORATION,
SPRING, 1966

ANNEX TABLE: COMMODITY CLASSIFICATION EMPLOYED IN THE RECONSTRUCTED 38-SECTOR INPUT-OUTPUT TABLE FOR 1959

Reconstructed Sector designation	Description [1]	Published Soviet table [2]
1. Ferrous ores	Ferrous ores and nonmetallic raw materials for ferrous metallurgy.	Part of 1.
2. Ferrous metals	Cast iron, steel, ferroalloys, rolled steel plate and sheet, rails and pipe.	Do.
3. Nonferrous ores	Nonferrous ores	Do.
4. Nonferrous metals	Nonferrous metals and industrial diamonds	Do.
5. Coking coal	Coke and products of coke-chemistry, including tar and coal-based oils.	2.
6. Metal products	Industrial metal products: nails, wire, bolts, pins, springs, chains, welding electrodes, and other small metal items; refractory materials.	3, 4.
7. Coal	Anthracite and lignite; coal briquets	5.
8. Oil	Extraction of oil, gas byproducts; oil refineries and processing of oil products.	6, 7.
9. Gas	Extraction of natural gas	8.
10. Other fuels	Peat, peat briquets, oil shales, liquid fuels from coal	9–11.
11. Electrical power	Generation of electrical power (thermal and hydro) and of steam as byproduct.	12
12. Electrical and power machinery and equipment.[4]	Steam boilers and equipment, steam and gas turbines, nuclear reactors, steam engines, diesel engines, and other prime movers; electrical machinery; electrical lighting fixtures; electrical household appliances.	13, 14.
13. Tools and instruments	Cable and wire products; woodcutting and metalworking tools, electrical tools, measuring tools; industrial instruments and gages, measuring and control apparatus; calculating and data processing equipment, including electronic computers; clocks, watches, optical, and photographic equipment, including household types; ball and roller bearings.	15, 19–21.
14. General machinery	Metal and woodworking tools, lathes, and drills; forging and pressing equipment; casting equipment; mining and metallurgical machinery and equipment; pumps and compressors; machinery and equipment for the woodworking, paper, textile, apparel, food, and printing industries; hoisting and transporting equipment; construction machinery.	16–18, 22–30.
15. Transportation machinery and equipment.	Transportation machinery and equipment; shipbuilding and aircraft production.	31.
16. Automobiles	Passenger automobiles, trucks, and other motor vehicles.	32.
17. Agricultural machinery and equipment.	Tractors and other agricultural machinery and equipment.	33.
18. Machinery not elsewhere classified.	Radioelectronics and communication equipment; machinery and equipment not elsewhere classified.	None.[3]
19. Metalworking	Sanitary engineering equipment; metalware and hardware; metal furniture; metal frames, structures, bridges.	35–37.
20. Repair of machinery	Repair of all machinery and equipment	38.
21. Abrasives	Abrasives and graphite products	39.
22. Mineral and basic chemicals	Mineral chemicals: sulfur, calcite, etc.; basic chemicals: ammonia, nitrate fertilizers, inorganic acids, and salts.	40, 41.
23. Synthetics and paints	Aniline dyes, synthetic resins and plastics, synthetic fibers, organic synthetics, synthetic rubber, paint and lacquer; pharmaceuticals and photochemicals.	42–46, 48.
24. Rubber products	Tires, tubes, hoses, and other rubber products; asbestos.	47.
25. Lumber and woodworking	Logging, lumber, and woodworking; furniture and other wood products.	49–52, 54.
26. Paper	Paper and paper products; wood pulp and cellulose	53.
27. Construction	Cement, alabaster, and other construction materials; brick, ceramic blocks, tiles, insulating materials, and concrete.	55.
28. Glass	Glass and porcelain-faience products	56.
29. Textiles	Textiles, hosiery, knitwear, and felt goods	57.
30. Apparel and footwear	Clothing and apparel, leather goods, footwear, and fur products.	58, 59.
31. Food	Processed foods: fish, meat, milk and dairy products, sugar, flour, bread, processed and canned goods, table salt, alcoholic and nonalcoholicbe verages; tobacco and products; candles, soap, perfumes and other cosmetics.	60–65.

See footnotes at end of table.

ANNEX TABLE: COMMODITY CLASSIFICATION EMPLOYED IN THE RECONSTRUCTED 38-SECTOR INPUT-OUTPUT TABLE FOR 1959—Continued

Reconstructed Sector designation	Description [1]	Published Soviet table [2]
32. Industry n.e.c.	Industrial products not elsewhere classified; printing and publishing; musical instruments and toys.	None.[3]
33. Construction	Construction—new and maintenance	66.
34. Agriculture	Agriculture—crops and animal husbandry	68–69.
35. Forestry	Forestry	70.
36. Transportation and communications.	Freight transportation, and communications serving production.	71.
37. Trade and distribution	Retail and wholesale trade, including public dining, supply and distribution services, procurement of agricultural products.	72.
38. Products n.e.c.	Metal scrap collection, publishing, noncommercial hunting and fishing, and other activities not elsewhere classified.	73.

[1] Based on Central Statistical Administration of the U.S.S.R., Forms and Instructions for 1959 Input-Output, translated by U.S. Department of Commerce, Office of Technical Services, Washington, D.C., 1962.

[2] Sector numbers refer to those in the published truncated version of the 1959 Soviet input-output table. TsSU, "Narodnoe khoziaistvo SSSR v 1960 godu," Moscow, 1961, pp. 103-143.

[3] These sectors were completely omitted from the published version of the table.

[4] M. & E.—machinery, equipment, and spare parts.

SECTION 2. INDUSTRY

SOVIET INDUSTRY TRENDS IN OUTPUT, INPUTS, AND PRODUCTIVITY

BY

JAMES H. NOREN

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SOVIET INDUSTRY TRENDS IN OUTPUT, INPUTS, AND PRODUCTIVITY

I. Introduction

A. SLOWDOWN IN SOVIET INDUSTRIAL GROWTH

Despite the declining trend evident since 1955, Soviet industrial output almost quadrupled during 1951–65 for an average annual rate of growth of 9.3 percent. This impressively high rate, equaling or surpassing those of the most rapidly growing economies of the Atlantic Alliance—Germany and Italy—reflects the importance assigned to rapid industrial development by the Soviet leadership. Almost 40 percent of the new investment since 1950 has been directed to renewing and expanding industrial capacity—the highest share of investments used for this purpose in any modern industrial nation. Industry's priority claim on the annual increments of trained manpower in the U.S.S.R. is exceeded only by the direct needs of the defense-space establishment. Thus the high rate of growth observed in Soviet industry can be explained, in large part, by the continued commitment of large doses of economic resources—capital investment and labor. But this is not the whole story.

In the U.S.S.R., as in all countries, the magnitude of economic growth depends on more than changes in the number of workers, the number of hours worked, and the services of tangible capital. To a large extent, rapid growth in the U.S.S.R. has resulted from high rates of increase in the efficiency with which labor and capital resources have been employed. One measure of this efficiency is an index of output per unit of capital and labor combined—that is, per unit of "inputs." In the United States, for example, in the first half of this century it has been estimated that one-half of the growth in national output was accounted for by growth in inputs and the rest by growth in the ratio of output per unit of inputs.[1]

Both official Soviet data and Western estimates show a marked decline in the rate of growth of industrial production in the U.S.S.R. in recent years. The agenda for economic reform in industry outlined by Premier Kosygin in September 1965 demonstrates that the Soviet leadership is not satisfied with the current performance of industry. This paper carries forward, with some modifications, estimates of industrial production which appeared in "Dimensions of Soviet Economic Power," a publication sponsored by the Joint Economic Committee 4 years ago.[2] These new estimates indicate that a slowdown in growth has indeed occurred in industry as a whole and in most branches of industry. After presenting these estimates of industrial production, this paper then examines the performance of Soviet indus-

[1] J. W. Kendrick, "Productivity Trends in the United States," Princeton, N.J., 1961, pp. 80–82.

[2] Rush V. Greenslade and Phyllis Wallace, "Industrial Production in the U.S.S.R.," Dimensions of Soviet Economic Power, Joint Economic Committee, U.S. Congress, 1962, pp. 119–136.

try since 1950 from the point of view of two basic elements of industrial growth: (1) the change in inputs of capital and labor and (2) the change in efficiency of resource use or factor productivity. The calculations of factor productivity presented in this paper are at best tentative estimates of the change in the ratio of outputs to inputs. Alternative calculations of factor productivity based on different schemes for weighting labor and capital inputs, however, do not affect materially the findings regarding the importance of a decline in the growth of factor productivity in explaining the deterioration in industrial performance.[3]

Some of the more important reasons for increases in factor productivity are (1) improvement in production techniques and in technology in general, (2) economies of scale of operation that result from specialization and division of labor as the economy or any particular branch of the economy expands, (3) a more efficient or better trained supply of labor that results from higher levels of education and skills and gradually improved health, (4) improved quality of plant and equipment to the extent it is not covered by the imperfect measures of the growth in capital services, (5) better administration and management of the economy from the highest managerial levels down to the enterprise director and shop foreman, and (6) improved quality and supply of raw materials used by industry.

The concluding section of this paper tries to uncover some of the more important causes of the slippage in productivity growth in Soviet industry. Variations in the relation of output to inputs in particular sectors at particular points of time suggest the possible effect of changes in Soviet policies with respect to industrial administration, the introduction of new technology, labor incentives, and the like. Finally, the output and productivity goals of the 1966–70 plan for industry are appraised in the light of past performance.

B. METHODS USED IN ESTIMATING OUTPUT, INPUTS, AND FACTOR PRODUCTIVITY IN INDUSTRY

1. Indexes of output

The index of production used in this report is an adaptation of an index published by the Central Intelligence Agency (CIA) in 1963.[4] Therefore it is a weighted index of the indexes calculated for output in each industrial branch. The various branch indexes are aggregated with value-added weights and the individual branch indexes represent a summation of the value of sample commodities in July 1, 1965 prices. However, the index used here differs in some important respects from the CIA index: (1) it revises some of the commodity series and extends all of them to incorporate data in the latest Soviet statistical abstracts, (2) some of the branch of industry samples are expanded to include more items or to disaggregate sample items into components that better reflect changes in the production mix, (3) it substitutes 1960 value-

[3] A number of attempts have been made to estimate the course of factor productivity in the Soviet economy—for example, those by Abram Bergson for gross national product (GNP) and by Raymond P. Powell for industrial production. Both studies showed a spectacular growth in factor productivity during 1951–58 compared with earlier periods, but both studies ended with 1958. Since 1958 the growth of Soviet industrial output has slowed considerably. (Abram Bergson, "National Income," and Raymond P. Powell, "Industrial Production," in Economic Trends in the Soviet Union, ed. by Abram Bergson and Simon Kuznets, Cambridge, Mass., 1963, pp. 1–3 and 150–202.)

[4] CIA. CIA/RR ER 63–29, "Index of Civilian Industrial Production in the U.S.S.R., 1950–61," September 1963.

added weights with an explicit capital charge for the 1955 weights used in the CIA index, and (4) the index for machine building and metalworking (MBMW) is an adjustment of the official Soviet gross value of output (GVO) indexes rather than an index based on a sample of civilian machinery items; therefore it includes both civilian and military production.

Because of these differences, the industrial production index presented in this paper rises more rapidly than the CIA index—by 10.0 percent per year during 1951–61 compared to 9.3 percent for the CIA index.[5] Three of the sectors most affected are ferrous metals, forest products, and MBMW. The ferrous metals index used in this report incorporated new data on the composition of Soviet steel output as reported in the "United Nations Quarterly Bulletin of Steel Statistics" as well as the increasingly important production of foundry pig iron, rolled stock for reprocessing, and exports of iron ore and pig iron. In contrast to the CIA index, the index for forest products used in this paper includes a series for production of furniture. The major difference between the index of industrial production presented here and that estimated by CIA, however, derives from the use in this paper of a modified version of the official Soviet GVO index for MBMW instead of a calculated index for civilian machinery. There is no Western estimate available that claims to represent both the civilian and the military components of MBMW. Because the data on inputs in MBMW relate to total outputs, not merely to civilian output, the index of output used in charting productivity trends also had to represent total output. The index was derived in a somewhat roundabout manner as follows.

First of all, it is assumed that the official GVO index for MBMW overstates growth for the same reasons that Western students have concluded that GVO indexes exaggerate growth in general. The question is, by how much? According to the estimates made in this paper, the ratios of average annual "actual" growth to average annual growth in GVO in the separate branches in Soviet industry during 1951–64 fall within a fairly narrow range. The ratio of "actual" (estimated) growth to growth in GVO is highest for ferrous metals (0.95) and lowest for chemicals (0.78). The ratios for all branches except ferrous metals and chemicals range between 0.87 and 0.92 (excluding the nonferrous and fuels branches, for which comparisons are not possible). However most of the reasons for believing that GVO indexes overstate growth apply with particular force to MBMW—for example, the likelihood of growing specialization and the high rate of introduction of new products into the index on a dubious price basis. Therefore, the proper discount of GVO growth in MBMW might be closer to that for chemicals than to the average for all sectors. For this paper three separate indexes of MBMW (and of industrial) output were calculated based on the alternative assumptions that for any given year the ratio of actual percentage growth in MBMW to the percentage growth in MBMW GVO was 0.9, 0.8, and 0.7. The indexes of output and factor productivity presented below are based for the most part on the MBMW and industrial production indexes that incorporate the second of the above alternatives—a 20-percent discount of the growth in GVO reported by the Soviets. Although it is not claimed that this particular alternative is a reliable barometer

[5] CIA, op. cit., p. 2.

of the precise extent of the growth of civilian and military machinery since 1950, it seems suitable for the purposes of this paper. The average annual growth in industrial production during 1951–65 is 9.3 percent under the assumption of a 20-percent discount of officially reported GVO growth in MBMW, while discounts of 10 and 30 percent result in average annual increases of 9.7 and 8.9 percent. This range is not large enough to make a material difference for the findings of this paper with respect to trends in output and productivity.

2. Indexes of inputs and factor productivity

Factor productivity for industry and nine industrial branches is calculated by dividing the indexes of output described above by indexes of labor inputs and capital stock combined.[6]

The capital stock indexes are derived with a few adjustments from official Soviet indexes. The indexes represent gross (undepreciated) reproducible fixed productive capital stock. They include structures and equipment and exclude land and other natural resources (except in the sense of mine shafts and diggings) and inventories. These assets are valued at replacement cost in what are basically 1955 prices rather than at original cost, and hence the index is a "constant price" index. The labor input is measured in two ways—by the number of workers employed and by the number of man-hours worked. These two measures differ significantly because hours worked per day and number of workdays per year have declined in the U.S.S.R. since 1955. Alternative combined input indexes using both employment and man-hours were calculated.

In U.S. practice, labor and capital inputs are combined into one index by the use of the share of income earned by each input as its weight. Data on wages of labor in Soviet industry are available, but there is no explicit accounting of a return on capital in the U.S.S.R. In order to construct possible weights for capital inputs, two alternative interest returns were assumed—8 and 13 percent—and were combined with amortization allowances to simulate gross return on capital.[7]

This system of weighting capital and labor inputs is clearly arbitrary, and different assumptions give different results. Alternative weights and indexes were calculated to illustrate the range of possible results. The alternative indexes use in turn (1) interest rates of 8 and 13 percent, and (2) 1950 and 1960 base years for the calculation of weights. A basic geometric or Cobb-Douglas formula was used to combine the capital and labor inputs.* One index of labor and capital inputs combined was selected for the primary presentation in the following section—a geometric index based on 1960 weights and an interest rate of 8 percent. For this particular index the base-period weights of capital and labor are intermediate in the range of alternatives. The other, alternative, indexes, however, also are considered in the analysis of the results.

[6] The method used to combine the labor and capital indexes is outlined in appendix A; the indexes of labor inputs are derived in appendix B, and the indexes of capital stock in Appendix C.

[7] These assumed interest rates do not seem to be too high. Under the new reform in industry a charge of 6 percent is to be levied on the undepreciated value of capital stock. L. Kantorovich argues that the "income norm" for capital (not the payment for capital) should be as high as 20 to 25 percent. (Ekonomicheskaya gazeta, No. 45, November 1965.) In other East European countries payments for capital stock, which again are not the return on capital, have ranged from 2 to 10 percent. (N. Mitrofanova, Planovoye khozyaystvo, No. 10, October 1965, pp. 58–60.)

* See appendix A for the derivation of the index formula used in calculating factor productivity.

Input and factor productivity indexes have been calculated for nine branches of Soviet industry as well as for industry as a whole. These nine branches do not cover all of industry—electric power and nonferrous metals and some small miscellaneous categories are missing. Because of this and because of questions regarding the comparability of the branch labor and capital inputs with each other and with output, the individual branch indexes are less reliable than those for all of industry.

C. LIMITATIONS ON THE MEANING OF THE RESULTS

The nature of the data and the calculations places severe limitations on the use of the results. The rate of growth in factor productivity depends on arbitrary assumptions as to the interest return on capital. For this reason alone, a direct comparison with similar calculations for U.S. industry is of limited value. Moreover, capital stock measurements in the U.S.S.R. and the United States are not comparable, and even the calculations of industrial output indexes are not as similar in their procedures as one would wish.

Comparisons of factor productivity between branches of Soviet industry may be attempted in a general way, but a precise analysis of the differences among the branches is hindered by the uncertainties of the data and especially by the assumption that the interest return on capital is the same in all branches.

The data on inputs and outputs, however, are considered to be reasonably consistent through time. Therefore, changes in trends in productivity for all industry and for the branches of industry are believed to be meaningful. In particular the slowdown in Soviet industrial growth in recent years appears to be indisputable, and one finding of this paper—that a decline in the growth of factor productivity contributed significantly to the slowdown—also appears to be indisputable. It is noteworthy that Soviet official data support these two conclusions unequivocally and that Premier Kosygin in his speech on the new 5-year plan in April 1966 underscored the need to restore rates of growth in labor productivity.

II. Growth of Industrial Output, Inputs, and Factor Productivity, 1951–65

A. INDUSTRY AS A WHOLE

1. Trends in output, combined inputs, and factor productivity

From 1950 to 1965 the U.S.S.R. achieved rapid industrial growth, but since 1955 this growth has tapered off. The increase in industrial output averaged about 11 percent annually during 1951–55, 9½ percent during 1956–58, 8½ percent during 1959–61, and less than 7½ percent during 1962–65.[8] The index of industrial production and its components are shown in table 1.

[8] These annual rates of increase were calculated on the assumption that output in MBMW is best approximated by a 20-percent discount of growth in the official GVO index. (See I. B, *1* above.) Under alternative assumptions of a 10- and 30-percent discount, there is the same pattern of decline in growth. With a 10-percent discount the rates of growth of industrial output for 1951–55, 1956–58, 1959–61, and 1962–64 are 11¼, 9½, 9, and 7½ percent; with a 30-percent discount of growth in MBMW output, the rates of growth for these periods are 10½, 9, 8, and 6½ percent.

TABLE 1.—*U.S.S.R.: Indexes of industrial production, 1950–65* [1]

	1960 value—added weights [2]	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Industrial materials	50.25	39.1	44.2	48.2	52.1	58.1	64.7	70.5	77.2	85.0	93.6	100.0	106.5	113.8	121.4	130.1	139.5
Electric power	4.27	31.4	35.8	41.0	46.2	51.7	58.2	65.6	71.9	80.7	90.7	100.0	112.1	126.5	140.7	156.4	172.5
Coal	10.85	50.1	54.3	57.8	61.1	66.5	75.0	82.2	88.6	95.1	97.8	100.0	100.0	102.0	105.0	109.2	113.6
Petroleum products and natural gas	3.37	27.2	30.3	33.9	37.9	42.7	47.5	56.6	66.6	76.7	87.8	100.0	112.3	127.4	141.6	155.1	169.0
Ferrous metals	7.37	38.8	44.6	50.2	55.6	61.3	68.0	73.7	78.1	83.9	91.9	100.0	108.1	116.8	124.1	134.0	146.1
Nonferrous metals	3.60	36.8	43.0	51.4	56.5	62.7	70.8	76.0	79.8	83.3	94.0	100.0	114.9	120.9	130.9	138.4	150.0
Forest products	9.31	50.8	58.1	59.3	61.1	69.0	72.8	75.4	81.3	89.1	99.0	100.0	101.3	105.3	111.2	116.4	119.2
Paper products	.85	45.6	51.1	56.5	63.8	70.1	73.3	79.0	85.8	91.6	95.7	100.0	105.9	113.4	119.7	128.6	145.5
Construction materials	6.53	20.5	24.1	27.8	31.7	36.8	44.0	50.3	60.5	72.6	86.7	100.0	110.5	120.4	127.2	135.7	146.2
Chemicals	4.10	31.6	37.0	41.4	46.1	51.5	59.3	65.1	72.9	82.0	91.6	100.0	107.9	117.6	129.4	145.4	162.2
Machine building and metalworking	30.38																
GVO growth discounted by 10 percent		26.8	31.2	35.7	40.8	46.9	54.8	61.8	69.1	77.6	88.3	100.0	113.5	129.1	144.4	156.6	169.5
GVO growth discounted by 20 percent		30.8	35.2	39.8	44.9	50.8	58.4	65.0	71.8	79.7	89.4	100.0	112.0	125.7	138.9	149.3	160.3
GVO growth discounted by 30 percent		35.4	39.9	44.4	49.4	55.0	62.3	68.5	74.8	81.9	90.6	100.0	110.5	122.3	133.6	142.4	151.5
Consumer nondurable goods	19.37	45.0	52.8	56.1	62.0	67.5	72.0	77.8	83.1	89.3	96.1	100.0	105.3	110.3	111.6	116.7	124.7
Light industry	11.24	44.4	53.1	55.7	60.9	67.9	72.0	76.7	81.8	88.5	94.5	100.0	103.2	107.5	109.8	114.4	116.9
Food industry	8.13	45.8	52.4	56.7	63.5	67.0	72.1	79.4	84.9	90.3	98.2	100.0	108.1	114.1	114.2	119.8	135.5
Aggregate industrial production with MBMW GVO growth	100.00																
Discounted by 10 percent		36.5	41.9	45.9	50.1	56.5	63.1	69.3	75.9	83.6	92.5	100.0	108.4	117.8	126.5	135.5	145.7
Discounted by 20 percent		37.7	43.1	47.2	51.9	57.7	64.2	70.3	76.7	84.2	92.8	100.0	107.9	116.7	124.8	133.3	142.9
Discounted by 30 percent		39.1	44.6	48.6	53.2	59.0	65.4	71 3	77.6	84.9	93.2	100.0	107.5	115.7	123.2	131.2	140.3
Official Soviet index of the gross value of industrial production [3]		33.0	38.5	42.9	48.0	54.4	61.1	67.6	74.4	82.1	91.4	100.0	109.2	119.7	129.4	138.9	150.8

[1] The branch indexes of industrial production, except for MBMW, are indexes of the gross value of the CIA sample, as described in the text. The MBMW (and the aggregate industrial production) index is presented in 3 variants for the reasons discussed in the text.

[2] The weights, except for electric power and nonferrous metals, are derived from the labor and capital weights shown in app. A, table 6. An 8-percent interest rate was applied to capital stock. The weights for electric power and nonferrous metals were estimated separately. Average annual capital stock and the amortization rate for capital stock for these branches are based on the same sources used for the other branches in table 6. Average annual employment of industrial production personnel in 1960 is estimated at 464,000 for nonferrous metals and 411,000 for electric power. Average annual earnings in nonferrous metals is estimated at 1,700 rubles and at 1,020 rubles in electric power. For employment, see Vladimir G. Treml "Economic Interrelations in the Soviet Union," *Annual Economic Indicators for the U.S.S.R.*, Joint Economic Committee, Washington, 1964, p. 203, and Gertrude Schroeder, "Soviet Industrial Labor Productivity," *Dimensions of Soviet Economic Power*, Joint Economic Committee, Washington 1962, p. 162. The estimates of average annual earnings are based on the same sources that were used to estimate average annual earnings for the other branches of industry in table 6.

[3] U.S.S.R., Central Statistical Administration: *Narodnoye khozyaystvo SSSR v 1964 godu*, Moscow, 1965, p. 124, *SSSR v tsifrakh v 1965 godu*, Moscow 1966, p. 54.

Of the three major sectors of industry, machine building and metalworking had the highest rate of growth during 1951–65, and the vigor of its expansion has held up best. The average annual growth in output of industrial materials and consumer nondurable goods was about the same in 1951–55; thereafter, growth in consumer nondurable goods slumped much more seriously than that of industrial materials.

Average annual rate of growth in output

[In percent]

	1951–65	1951–55	1956–58	1959–61	1962–65
Industrial materials	8.8	10.6	9.5	7.8	7.0
Machine building and metalworking	11.9	13.7	10.9	12.0	10.1
Consumer nondurable goods	7.1	9.9	7.4	5.7	2.5
Total industry	9.3	11.2	9.5	8.6	7.3

Between 1950 and 1965, Soviet industrial output increased by 279 percent while inputs of capital and labor combined increased by 106 percent. Thus, if growth had been based only on use of additional inputs, it would have been only a little more than half of the average annual growth actually attained. In other words, without an increase in resource productivity, industrial output would have advanced at an average annual rate of 4.9 percent instead of the actually observed growth of 9.3 percent. The balance of total industrial growth was associated with increases in factor productivity—averaging 4.2 percent annually for the entire period. But this advance in the rate of growth in factor productivity (shown in table 2) has been far from steady—accelerating through most of 1951–58, dropping slightly in 1959–61, and then declining abruptly in 1962–65. These trends in factor productivity reflect the trends in output and in the combined inputs of capital and labor (fig. 1). The growth in output fell between 0.7 and 1.8 percentage points in each of the subperiods 1956–58, 1959–61, 1962–63, and 1964–65. The index of inputs increased at 6.4 percent per year during 1951–55; then the rate of increase declined to 3.6 percent per year during 1956–58 and to 3.0 percent per year during 1959–61. Following the completion of the reduction in the length of the workweek, the growth in inputs of labor and capital rebounded to 5.3 and 5.8 percent during 1962–63 and 1964–65. Meanwhile the growth in factor productivity climbed from an annual rate of 4.5 percent during 1951–55 to 5.7 percent in 1956–58. The rate of increase in factor productivity sagged slightly in 1959–61 to 5.4 percent and then precipitously to 2.2 and 1.1 percent in 1962–63 and 1964–65. The most rapid growth in factor productivity (5.7 percent and 5.4 percent) occurred during 1956–58 and 1959–61 as the rate of growth in inputs continued to decline. In 1962–65, however, there was a further slowdown in the growth of output in the face of a sharp increase in the rate of growth of inputs. Consequently the growth in factor productivity fell to the lowest annual rate of the whole period.

TABLE 2.—*U.S.S.R.: Output, input, and factor productivity trends in industry, 1950–65*

Estimated indexes (1950=100)

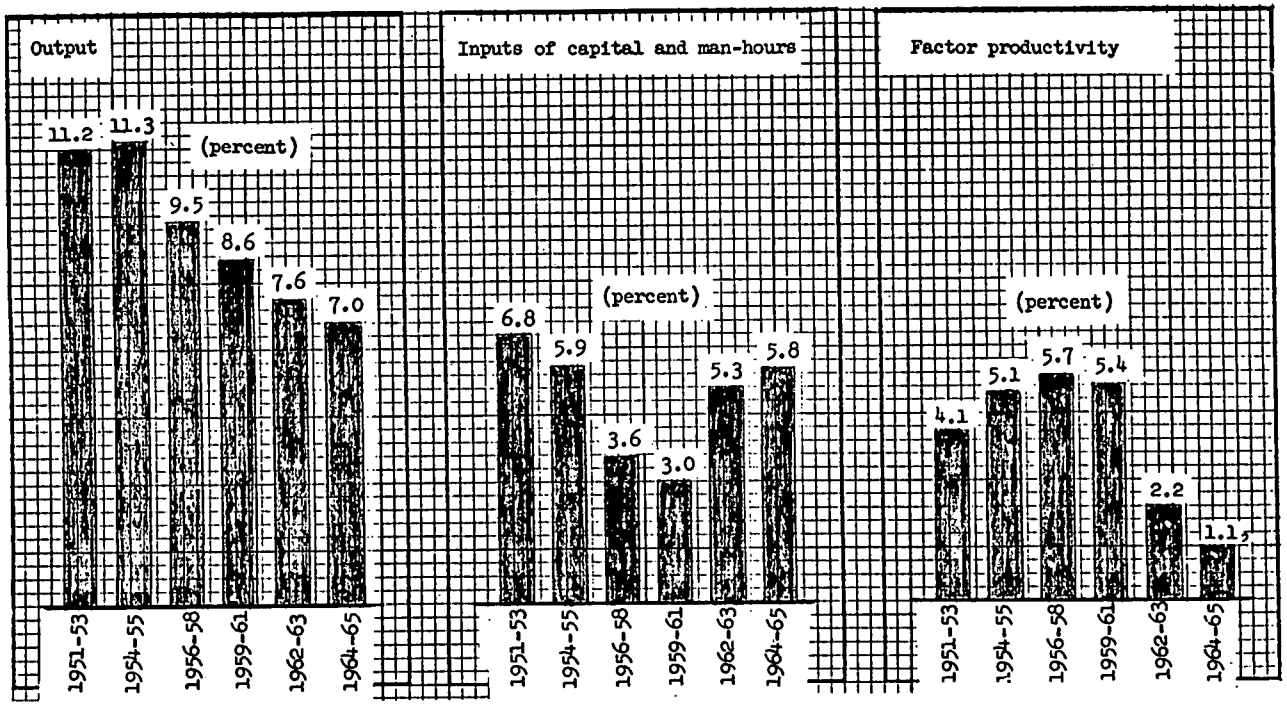
	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Index of output [1]	137.5	170.3	186.4	203.5	223.4	246.2	265.2	286.2	309.6	331.1	353.6	379.2
Index of capital stock [2]	137.1	170.6	191.0	211.7	235.6	262.2	292.4	327.0	362.0	403.4	447.4	491.0
Indexes of labor services: [3]												
Adjusted employment	117.1	126.5	130.6	133.7	139.2	144.0	151.1	159.1	164.2	168.9	174.4	181.9
Man-hours per worker	99.3	98.9	96.0	94.1	91.8	89.4	84.8	80.1	79.9	80.2	80.8	(5)
Total man-hours worked	116.3	125.1	125.4	125.8	127.8	128.7	128.1	127.4	131.2	135.5	140.9	[6] 147.0
Indexes of inputs: [4]												
Capital and man-hours	121.8	136.5	141.1	145.5	151.7	157.1	161.4	165.9	174.3	183.9	194.7	206.0
Capital and employment	122.4	137.5	144.3	152.1	161.3	170.3	181.8	194.7	204.9	215.5	227.0	240.2
Indexes of factor productivity: [4]												
Man-hours	112.9	124.8	132.1	140.0	147.3	156.7	164.3	172.5	177.6	180.0	181.6	184.1
Employment	112.3	123.9	128.3	133.8	138.5	144.6	145.9	147.0	151.1	153.6	155.8	157.9

Average annual rates of growth (percent)

	1951–65	1951–55			1956–61			1962–65	
		1951–55	1951–53	1954–55	1956–61	1956–58	1959–61	1962–63	1964–65
Output	9.3	11.2	11.2	11.3	9.0	9.5	8.6	7.6	7.0
Input:									
Capital and man-hours	4.9	6.4	6.8	5.9	3.3	3.6	3.0	5.3	5.8
Capital and employment	6.0	6.6	7.0	6.0	6.0	5.5	6.5	5.2	5.6
Factor productivity:									
Capital and man-hours	4.2	4.5	4.1	5.1	5.5	5.7	5.4	2.2	1.1
Capital and employment	3.1	4.4	3.9	5.0	2.9	3.8	2.0	2.2	1.4

[1] The variant incorporating a 20-percent discount of the growth in MBMW GVO, table 1.
[2] From table 8.
[3] From table 7.
[4] From table 9. The index of inputs is a weighted index of labor inputs (measured in man-hours or employment) and capital stock (at an interest rate of 8 percent). The inputs are combined using 1960 base-year weights in a geometric function (see appendix A).
[5] Not available.
[6] Assuming no change in hours worked per year by the average industrial worker.

Figure 1



USSR: Estimated average annual rates of industrial growth: Output-inputs of capital and man-hours, and factor productivity, 1951-65

The trends in inputs and factor productivity suggest that a pronounced change occurred during 1962–65 in the causes of the slowdown in the growth of industrial output. Through 1961, successive declines in the rate of growth in inputs account for the slowdown in output. After 1961 the slower growth in factor productivity is dominant.

2. Trend in capital services

Although the growth of total inputs into industry varied considerably during 1951–65, the growth of capital services as represented by productive capital stock did not.* Capital stock increased rapidly and evenly over the whole period at a rate of between 11 and 12 percent per year. The capital-labor ratio in industry more than tripled over the 15 years. This trend in capital formation, in turn, illustrates the hard core of the Communist doctrine of economic growth—up to the present at least. Although other priorities and basic economic conditions have changed, an overriding goal in peacetime has been to push the growth of productive fixed capital. When the rate of increase in new investment in industry fell off after 1959, retirement policies apparently were changed to keep up the growth of capital stock.

Given the fixed rate of increase in capital stock and the assumption that capital services vary proportionately with capital stock, any changes in the rate of growth of industrial output must be explained by the behavior of either labor inputs or factor productivity. The effect of changing rates of retirement of fixed capital on the quality of capital services and thence on output would appear in the trend in factor productivity.

3. Trends in employment and man-hours

Inasmuch as capital services grew steadily over the period, the behavior of labor inputs explains the variation in the growth of the combined inputs index during 1951–65. The calculations of inputs and factor productivity described above use man-hours as the measure of labor inputs.** Increments in total man-hours sagged drastically after 1955 and actually declined from 1959 to 1961. On the other hand, average annual employment had a distinctly different trend from that of man-hours. Although the rate of increase of industrial employment was reasonably stable during 1951–65 (between 2.4 and 5.4 percent per year), the reduction in hours worked per year by each worker, primarily during 1956–61, brought about a sharp break in the trend of total man-hours worked. Total employment in industry rose by 26 percent between 1955 and 1961, but a reduction of 19 percent in the number of hours spent on the job by each worker during a calendar year resulted in a slight net increase of only 2 percent in total man-hours worked in industry. Most, but not all, of this reduction in hours worked per year was due to a shortening of the workweek.[9]

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* See appendix C for a more detailed description of the derivation of the indexes of capital services.

** See appendix B for a more detailed description of the derivation of indexes of labor inputs.

[9] More than ⅔ of the reduction of 19 percent in the hours per worker per year was caused by a reduction of 13 percent in the scheduled workweek. The balance of the reduction reflected 5 additional days off on the average for the year (holidays and vacations, 3 additional days a year for maternity and sick leave, and a shorter workday on the days preceding holidays). Part of this reduction in days worked also reflects a changing age and sex composition of the industrial labor force over time.

It has been argued that when hours worked per week are reduced, labor productivity per hour increases.[10] When reductions in the workweek take place in the area of 40 to 50 hours per week (as did the Soviet reductions after 1955), it is difficult to believe that a decline in fatigue is responsible for the major part of any increase in output per man-hour. Instead, it is more likely that improvements in management (perhaps spurred by the imposition of a shorter workweek) and the substitution of capital for labor inputs explain most of this increase. If so, the improved management falls within the definition of productivity gains as used in this paper. To the extent that reductions in the workweek did cause employees to exert more effort per hour after 1955, factor productivity gains based on man-hours are overstated in 1956–58 and especially in 1959–61, when the reduction was most rapid.

To minimize the possible impact of reduction in hours on labor productivity and, therefore, on factor productivity, the comparisons of growth of factor productivity can be adjusted by regrouping the data. Of the reduction of 18 percent in hours worked per year per worker between 1955 and 1965, little more than half occurred before 1960, the rest in 1960–65. Thus when the average annual rates of increase in factor productivity in 1956–59 and 1960–65 are compared, the effect of the reduction in man-hours on the relative size of the two rates should be negligible. The decline in annual growth of factor productivity is still striking—from 5.9 percent per year during 1956–59 to 3.0 percent per year during 1960–65.

Naturally, the rate of growth in factor productivity after 1955 differs markedly, depending on whether man-hours or employment is used to measure the growth of labor inputs. When factor productivity is calculated by using employment for the labor inputs, the gain in productivity is lowest in 1960 and 1961, recovers in 1962 and then begins to fall off again. When man-hours are used, gains in productivity are dampened in 1960–61 and melt away steadily and rapidly from 1962 on. Because of the uncertain impact of the reduction in the length of the workweek on the quality of labor or management, it is impossible to say how much or when factor productivity would have slowed down in the absence of a shortened workweek.

In terms of measuring the change in the efficiency with which actual inputs are used, man-hours appear to be the suitable yardstick of changes in labor inputs. From another point of view, however, the growth in factor productivity calculated in terms of employment is of interest. To the Soviet industrial planners the industrial labor force is the labor input. By carrying out an extensive workweek reduction, the Soviet authorities sacrificed a great deal of potential gain in output; the gap in table 2 between factor productivity based alternatively on man-hours and employment suggests the extent of this loss, although it is not an accurate measure of the loss because of the

[10] Not only because of the usual conceptual reasons—changing factor proportions, for example—but because of a decline in fatigue and because of better morale. Edward Denison puts the question in the following way:

"* * * Neither an hour's labor nor a year's labor is the same amount of work when a man works 72 hours a week as when he works 48 or 35. As the hours are shortened, the product turned out in an hour usually increases as a direct consequence of the change in hours." In his study of U.S. growth, Denison uses a formula which assumes that marginal reductions of hours to a level of about 49 hours per week cause no loss in output per man. Thereafter, further cuts in the workweek bring increasing proportionate losses in output per man: with a workweek of 40 hours per week, a reduction of 1 percent in the workweek is assumed to cause a reduction of 0.6 percent in output per man. ("The Sources of Economic Growth in the United States", Committee for Economic Development, Supplementary Paper No. 13, January 1962, p. 35, 40.)

interaction between shorter hours, labor effort, and management initiative mentioned above.

4. Alternative measures of factor productivity

The indexes of factor productivity presented above are based on a particular set of weights for labor and capital inputs and a geometric index formula. The weights reflect (*a*) an interest rate of 8 percent on gross capital stock, (*b*) the value of capital stock in 1960, (*c*) the average annual earnings of labor in 1960, and (*d*) employment in industry in 1960. The result of using different weights for labor and capital inputs and an arithmetic formula can be judged by examining the data in table 3, which show four alternative calculations of factor productivity. If 1950 is used as the base year for calculating the weights of labor and capital inputs and if the interest rate on fixed capital stock is assumed to be 8 percent, as in variant A in table 3, the weight given to labor inputs is .80 and to capital inputs is .20. In variant B, which is used in table 2 and in the subsequent analysis, an interest rate on capital stock of 8 percent is also used when the base year is 1960. Thus the weight for labor inputs falls to .72 and the capital weight rises to .28 because capital stock grew more rapidly than industrial earnings between 1950 and 1960. In variant C the weight attached to labor inputs is still lower (.64) as a result of using an interest rate of 13 percent and 1960 as the base year.

Factor productivity for all industry is also calculated in table 3 by using an arithmetic production function (variant D) with an 8-percent interest rate and a 1960 base year. A comparison of the growth in factor productivity in variants B and D shows some of the range in possible effects of using different combinations of labor and capital over time. The arithmetic function implies perfect substitutability—that is, that changing the input mix by increasing one input while holding the other(s) constant results in a constant absolute increase in output. The geometric function, however, projects smaller gains when the input mix is changed: increasing one input while holding the other constant results in decreasing increments to output.[11] When labor and capital indexes are combined arithmetically on a 1960 base, factor productivity grows more rapidly before 1960 and less rapidly after 1960, compared to factor productivity calculated with a geometric formula.

TABLE 3.—*U.S.S.R.: Comparison of four variants of growth in factor productivity in industry, selected periods, 1951–65* [1]

Variant	Alternative functions and weights				Average annual rates of growth of factor productivity (percent)			
	Function	Base year	Interest rate (percent)	Labor coefficient (percent)	1951–55	1956–58	1959–61	1962–65
A	Geometric	1950	8	80	5.0	6.5	6.4	2.2
B	do	1960	8	72	4.5	5.7	5.4	1.6
C	do	1960	13	64	4.0	4.8	4.5	1.1
D	Arithmetic	1960	8	72	5.2	6.4	5.6	1.2

[1] The rates of growth of factor productivity based on the geometric functions (with man-hour labor inputs) are calculated from table 9. Variant D has been estimated separately using the same weights and input indexes as in variant B. The weights are derived in appendix A, table 6.

[11] The arithmetic function used has an infinite elasticity of substitution of one factor for another, while the geometric index has an elasticity of substitution of unity. Thus, a large area of possible "true" factor substitution characteristics is bracketed.

Variant B was selected for primary presentation in table 2 and in the succeeding tables and discussion. This does not mean that variant B is the "right" index, only that it represents a middle-of-the-road choice among alternatives. The weights and formula should reflect the marginal products of capital and labor and the elasticity of substitution of one for the other. However, as it is not possible to give these theoretical concepts any concrete, statistical meaning in the Soviet context, no attempt has been made to discover the "right" productivity index for the U.S.S.R. The use in this paper of variant B is a convenient simplification, and in any case the analyses and findings of this paper regarding patterns of productivity appear to be valid regardless of the input weights and formula used.

Although these alternative formulations of factor productivity produce a considerable range in the level of productivity gains, they confirm the picture of a general rise in the rate of increase from 1951–55 to 1956–61, followed by a precipitous decline in the rate of advance in 1962–65. It is this pattern of factor productivity, rather than the precise level, that is important for the analysis of recent developments in Soviet industry.

B. TRENDS IN OUTPUT, INPUTS, AND FACTOR PRODUCTIVITY IN THE BRANCHES OF INDUSTRY

1. Branch coverage

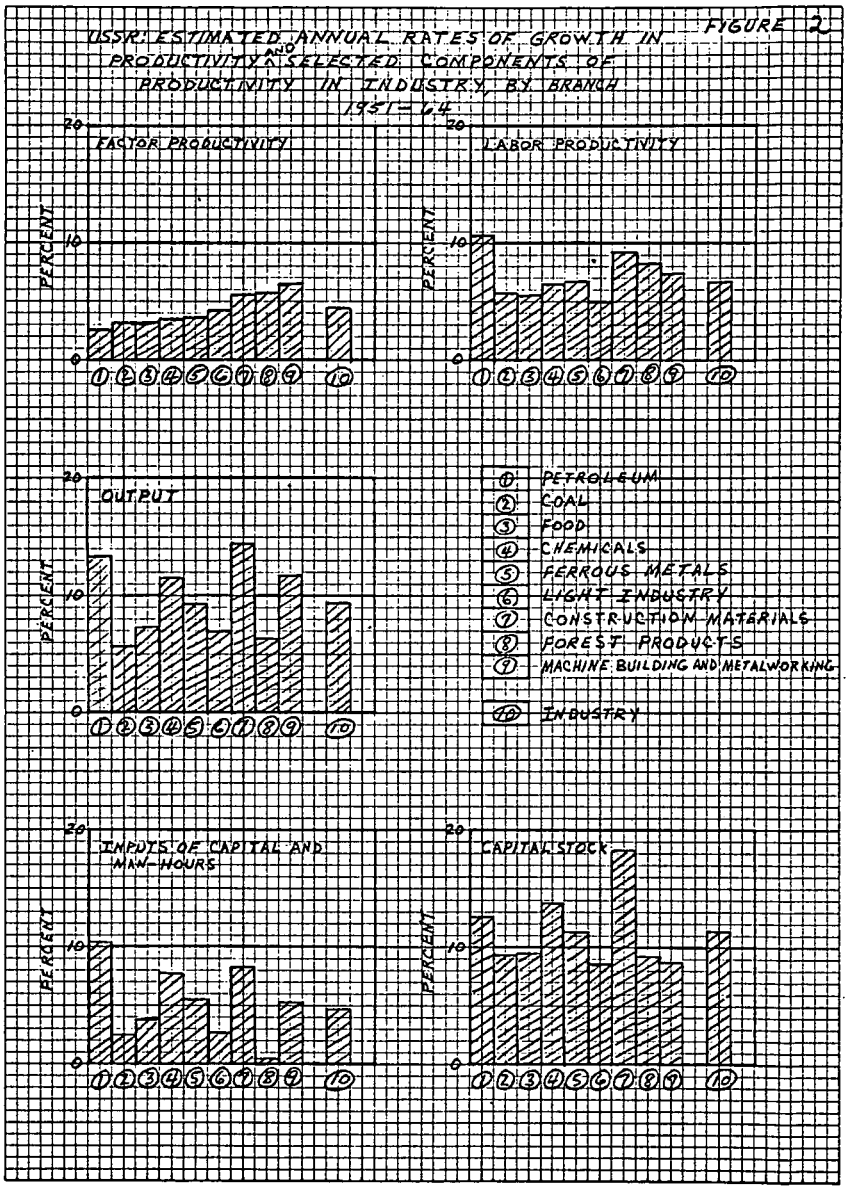
The nine branches discussed in this section are major components of the Soviet industrial classification—a system quite different from that of the United States. In general, mining is not separated from manufacturing in the Soviet system, and most of the branches are highly aggregative: ore mining is lumped together with steelmaking and fabrication in the ferrous metals branch; the petroleum products and natural gas branch includes both extraction and refining; and the forest products branch is an amalgam of timber cutting, wood processing, and papermaking. Construction materials includes the mining of raw materials but excludes steel and timber used in construction. Light industry includes textiles, shoes, and leather products. Chemicals includes rubber and asbestos products.

Within these broad categories, there have been radical changes in the nature of branch output. Thus there has been widespread substitution of gas and oil for coal and concrete for brick, and synthetic fibers and plastics have been emphasized at the expense of natural materials. In the machine building industry the relative importance of military hardware probably varied greatly during 1951–65.

The nine branches for which factor productivity trends have been calculated do cover most of industry, however. In 1964 these branches employed 90 percent of industrial workers and had 75 percent of industrial productive capital stock. The only major components of industry excluded are the nonferrous metals and electric power branches, where the information required for the calculations was missing. Because of the breadth of the branch definitions and because of some of the gaps in coverage, the analysis of branch trends which follows is less illuminating than it would be if more disaggregation were possible.

2. Output and factor productivity in the branches of industry

The indexes of output, combined inputs, and of factor productivity are presented for each of nine branches of industry for 1951–64 in table 4.* It can be seen from figure 2 that the differences among



*The indexes run only through 1964, as it is not possible to measure inputs or factor productivity by branch during 1965.

the branches in the rate of growth of factor productivity are less than the differences in the growth of aggregate labor and capital inputs. Therefore, variations among the branches with respect to growth in inputs are a better explanation of branch differences in the growth of output over the period 1951–64 as a whole than are variations in the rate of increase in factor productivity. These differences are discussed in the following section.

Second, it appears that the growth of factor productivity does not correspond closely with the rate of increase in capital stock—either among the branches or within the same branch over time. Although new technology is introduced in the process of investing, evidently the rate of increase in capital stock is not critical for the trend in factor productivity. The causes of variation in the rate of growth in factor productivity seem to be much more complex. Finally, as one would expect, the growth in labor productivity by branch corresponds loosely to the growth of capital stock but less so to the growth in factor productivity.

TABLE 4.—*U.S.S.R.: Estimated average annual rates of growth of outputs, inputs, and factor productivity in industry, by branch, selected periods, 1951–64* [1]

	1951–64	1951–55			1956–61			1962–64
		1951–55	1951–53	1954–55	1956–61	1956–58	1959–61	
All industry: [2]								
Output	9.4	11.2	11.2	11.3	9.0	9.5	8.6	7.3
Inputs	4.9	6.4	6.8	5.9	3.3	3.6	3.0	5.5
Factor productivity	4.4	4.5	4.1	5.1	5.5	5.7	5.4	1.7
Ferrous metals:								
Output	9.3	11.8	12.7	10.6	8.0	7.3	8.8	7.4
Inputs	5.5	6.4	7.3	5.0	4.4	3.0	5.7	6.1
Factor productivity	3.6	5.1	5.0	5.3	3.5	4.1	2.9	1.2
Coal:								
Output	5.7	8.4	6.9	10.8	4.9	8.2	1.7	3.0
Inputs	2.5	6.1	5.0	7.7	.3	3.9	−3.1	1.3
Factor productivity	3.1	2.2	1.8	2.8	4.6	4.2	5.0	1.6
Petroleum products and natural gas:								
Output	13.2	11.8	11.8	11.9	15.4	17.3	13.6	11.4
Inputs	10.3	13.4	12.5	14.9	9.3	10.8	7.9	7.1
Factor productivity	2.7	−1.4	−.6	−2.6	5.6	5.9	5.3	4.0
Machine building and metalworking: [2]								
Output	11.9	13.7	13.4	14.1	11.5	10.9	12.0	10.1
Input	5.1	6.0	6.4	5.4	3.6	3.4	3.7	6.5
Factor productivity	6.5	7.2	6.5	8.3	7.6	7.2	8.1	3.3
Construction materials:								
Output	14.5	16.5	15.7	17.8	16.6	18.2	15.0	7.1
Inputs	8.2	10.4	11.0	9.5	9.1	10.9	7.4	3.0
Factor productivity	5.8	5.6	4.2	7.7	6.8	6.6	7.1	3.6
Light:								
Output	7.0	10.1	11.1	8.7	6.2	7.1	5.2	3.5
Inputs	2.6	5.3	6.1	4.1	.4	.1	.8	2.8
Factor productivity	4.2	4.6	4.7	4.4	5.7	7.1	4.4	.7
Food:								
Output	7.1	9.5	11.5	6.6	7.0	7.8	6.2	3.5
Inputs	3.9	4.9	5.5	3.9	2.5	4.0	1.1	5.0
Factor productivity	3.1	4.4	5.7	2.6	4.3	3.7	5.0	−1.4
Chemicals:								
Output	11.5	13.4	13.4	13.4	10.5	11.4	9.6	10.5
Inputs	7.9	7.8	8.1	7.4	4.9	2.9	7.0	14.5
Factor productivity	3.3	5.2	4.9	5.6	5.3	8.3	2.5	−3.5
Forest products:								
Output	6.2	7.7	6.8	9.0	5.7	7.0	4.4	4.9
Inputs	.4	2.9	(3)	(3)	−2.7	−1.6	−3.6	2.3
Factor productivity	5.9	4.6	(3)	(3)	8.6	8.8	8.3	2.6

[1] These calculations are based on the summary data on branches of industry presented in table 9, appendix D. In each case the growth in inputs and factor productivity relies on the use of a geometric function with input coefficients based on 1960 base-year weights and an interest rate of 8 percent on capital stock.

[2] The rates of growth of output (and therefore factor productivity) in industry and machine building and metalworking are based on the variant of output in MBMW which incorporates a 20-percent discount of the growth in official GVO.

[3] Not available.

Over the whole period 1951–65 three branches in the area of industrial materials—construction materials, petroleum products and natural gas, and electric power—boosted their output most rapidly (see table 5). Machine building and metalworking followed in terms of the level of the average rate of growth; it ranked consistently from third to fifth during the four subperiods 1951–55, 1956–58, 1959–61, and 1962–65. The change in the structure of output of industrial materials is shown by comparing the growth pattern of the three leading branches with those of coal and forest products which were quite consistently in 10th and 11th place in a ranking of the 11 branches by rate of growth during the various subperiods. Based on these rankings, it is difficult to discover any change in the relative emphasis placed upon the consumer goods industries over time; the food and light branches were generally in eighth and ninth place.

TABLE 5.—*U.S.S.R.: Ranking of branches of industry according to rate of growth of output, selected periods, 1951–65* [1]

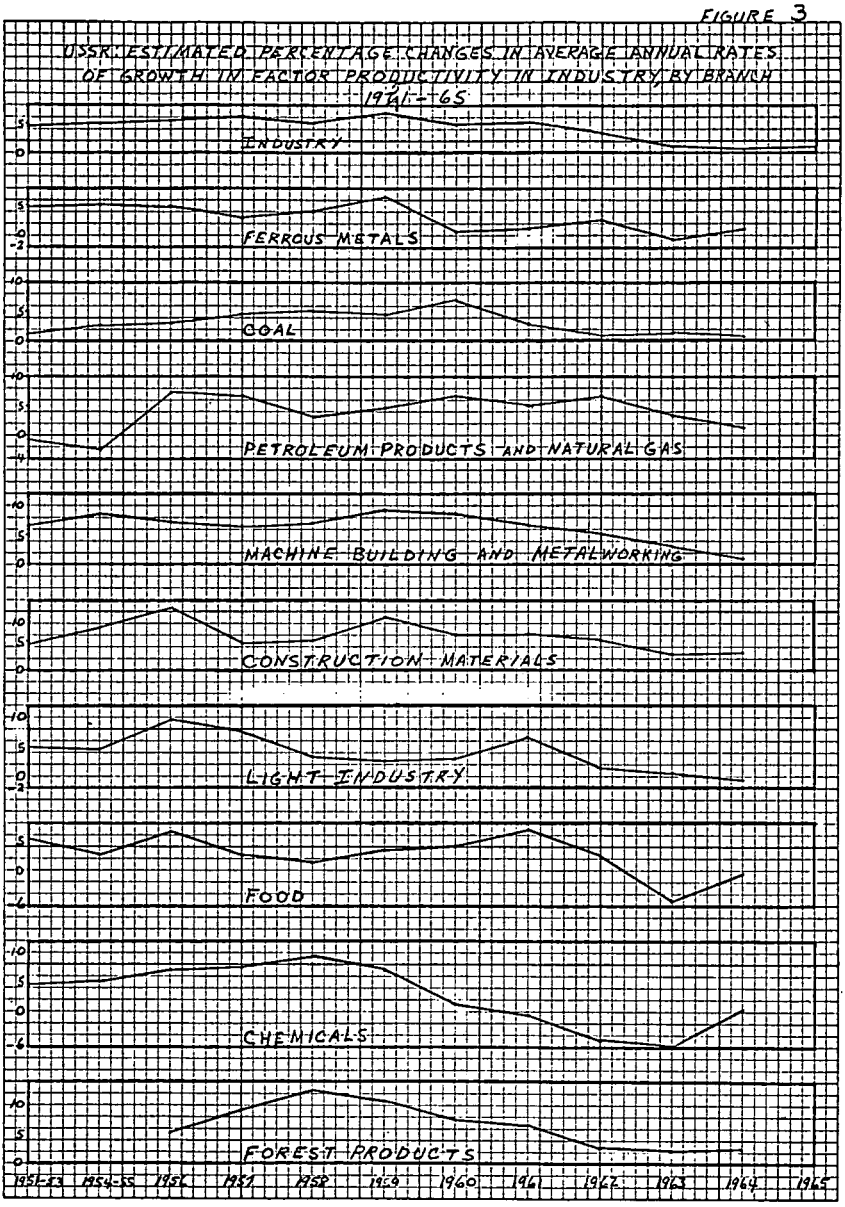
	1951–65	1951–55	1956–58	1959–61	1962–65
Construction materials	1	1	1	1	6
Petroleum products and natural gas	2	7	2	2	2
Electric power	3	5	3	4	1
Machine building and metalworking	4	3	5	3	4
Chemicals	5	4	4	6	3
Nonferrous metals	6	2	11	5	7
Ferrous metals	7	6	8	7	5
Food	8	9	7	8	8
Light industry	9	8	9	9	11
Forest products (including paper)	10	11	10	10	9
Coal	11	10	6	11	10

[1] Based on indexes presented in table 1.

Although figure 2 reveals a marked similarity in the average annual rates of growth of factor productivity in the individual branches of industry over the whole period, 1951–64, this uniformity disappears when branch trends within this period are examined. In figure 3 the average annual rates of change in factor productivity year-by-year are presented for all industry and for the nine branches. Not one branch follows closely the trend in factor productivity for all industry from the point of view of exhibiting a fairly steady rise in the rate of increase in factor productivity through 1958–59 followed by a slight decline in 1960–61 and a sharp drop thereafter. Percentage gains in the coal, machine building, chemical, and forest products branches of industry, however, do climb upward unevenly, reach a peak in the few years before 1961, and then fall off abruptly. The most pronounced decline in gains in factor productivity occurs in the chemical industry after 1958 at a time when the priority of this branch was increased and the supply of inputs accelerated. Against this background the concern shown by the Soviet leadership over the performance of the chemical industry is understandable. Furthermore, it is conceivable that this very concern has led to a stuffing of inputs into the chemical industry at a rate beyond its capacity to digest.

Three other branches have a somewhat similar pattern of growth in factor productivity. Gains in factor productivity in construction materials and the light and food branches peaked in 1956 before slumping. After some recovery through 1961, the rate of increase in pro-

FIGURE 3



ductivity again falls off sharply. Gains in ferrous metals, in contrast, are quite constant through 1959 before dwindling away. The last branch of industry covered in this report—petroleum products and natural gas—displays the most distinctive behavior of factor productivity. After attaining a plateau in 1956–57 the annual rate of increase in factor productivity declines sharply in 1958 and then climbs steeply in 1959–62 only to fall markedly in 1963–64.

These differences in trends in factor productivity among the branches at a given point in time show that rates of growth of productivity in industry cannot be forecast merely by predicting probable changes in the relative importance of the various branches. The high points of gains in factor productivity in the branches of industry are found over a broad span of years. When the rate of increase in factor productivity in industry jumped from 5.2 percent in 1958 to 6.4 percent in 1959, only five of the nine branches managed to raise their percentage gains. Moreover, four of the nine branches pushed up their rates of gain in factor productivity in 1960 while the rate of advance fell significantly in industry as a whole. Only in 1962–64 were the changes in the rate of increase in factor productivity in the same direction for almost all branches.

3. Trends in labor and capital services in the branches of industry

The unequal provision of additional inputs, as noted earlier, explains most of the difference in rates of growth of the branches of industry. Changes in the rate of increase of weighted inputs were presented in table 4; underlying trends in labor and capital services are outlined here. Table 9 in appendix D presents for all industry and each of nine branches of industry indexes of output, capital, and labor services individually and combined, and the calculations of factor productivity, labor productivity, and capital productivity.

In all of the branches the introduction of a shorter workweek after 1955 produces an uneven rate of increase in man-hour inputs. In addition, the overall extent of the increase differs greatly among the branches. For the most part the increases were roughly comparable before 1955 but then diverged. By 1962, man-hour inputs in the ferrous metals, petroleum products, and light industry branches were not much different from 1955; in the coal, food, and forest products branches, man-hour inputs were appreciably less in 1962 than in 1955. The large increase in man-hour inputs occurred in machine building, construction materials, and chemicals.

Although the rate of growth in capital stock in all industry was remarkably stable during 1951–64, the growth in the individual branches varies widely over time. For example, the rate of increase of capital stock in the coal industry falls off noticeably after 1959. In light industry the rate of growth picks up after 1958 and in chemicals in 1959 and again in 1962. From 1959 to 1961 the rate of increase in output in chemicals slowed in spite of acceleration of both capital and labor inputs. The trends are consistent with recurrent reports of difficulties in completing new chemical plants and starting production in them.

As a result of the unequal growth of man-hours and capital stock in the branches, the capital-labor ratios changed in quite different degrees. Thus, in construction materials it increased by 430 percent and in machine building and metalworking by only 84 percent.

Percentage increase in capital-man-hours ratio, 1951–64

Construction materials	430	Chemicals	219
Forest products	332	*All industry*	218
Petroleum products and gas	291	Food	189
Coal	251	Light	146
Ferrous metals	224	MBMW	84

Of course the increase in the capital-labor ratio was particularly large in each branch in the late 1950's when the leadership carried out the reduction in the workweek. The increases in the capital-labor ratio are rather weakly related to the increases in man-hour productivity in these same nine branches.[12]

C. RELIABILITY OF RESULTS

In spite of the caveats that can be entered in interpreting the results of this paper, it should be pointed out that, for Soviet industry as a whole, the differences in growth of factor productivity in the subperiods are quite large. In particular, the decline in the growth in factor productivity in 1962–64 is substantial and appears in nearly all branches of industry. When alternative methods of weighting inputs are tried, the general trend in factor productivity is not affected greatly. Nevertheless, potential biases abound in a study of this kind. The question is whether these biases might upset the findings outlined above.

First of all, there are many deficiencies in the index of actual output. The output index appears to be the best available but still depends on the limited amount of physical output data disclosed by the U.S.S.R. Then too, the industrial output and MBMW indexes depend on the fairly arbitrary procedure of discounting the growth of the value of output as officially reported for MBMW. One test of the validity of the trends in factor productivity derived with the output index presented earlier is to substitute the official Soviet index of industrial output in the productivity calculations. The average annual rates of growth in factor productivity in industry (in percent) are as follows:

	1951–53	1954–55	1956–58	1959–61	1962–65
Calculated from Soviet output index (GVO).....	6.1	6.6	6.5	6.7	2.7
Calculated from the output index used in this paper..	4.1	5.1	5.7	5.4	1.6

Although the rate of growth in factor productivity is higher in all periods when the Soviet index is used, the general pattern is similar. Both series show a strikingly similar decline in 1962–65.

The indexes of labor inputs also have their problems. For example, bias in the measure of employment by branch may have arisen because of changes in coverage and reporting of workers in industrial cooperatives. The most important problem in labor trends, however, is the estimate of the timing of the reduction of hours in the branches of industry. The rates of increase in productivity during each year, 1957–61, would be sensitive to changes in this estimate but probably not those of 1962–64 in comparison with the average of preceding years, as the full extent of the reduction is known. The main difficulties with the capital stock estimates result from the effects of having to use

[12] The Kendall rank correlation coefficient is 0.5; the probability of a value this large in the absence of any association between growth in the capital-labor ratios and growth in output-labor ratios is 0.038.

distributions of industrial capital stock by branch in terms of original cost of the assets until 1953 in the derivation of the branch indexes. This is more important for trends in factor productivity for branches than for the trend in all industry.

Another source of uncertainty in interpreting the results is the absence from the analysis of several factors. Inputs of materials and inventories are not included. The fortunes of the light and food industries, particularly, could be explained with more confidence if more were known about materials availability in 1951–64. Also, the performance of industries such as coal, ferrous metallurgy, and petroleum products and natural gas was influenced by changes in the quality of raw material sources. For example, a substantial part of new investment in ferrous metals has gone into facilities for the beneficiation of low-grade ores. If the source of raw materials is within the branch, a decline in factor productivity caused by problems in respect to raw materials at least singles out the right branch for blame; when the raw materials source is outside the branch, the factor productivity index may point to the wrong party—as when coking coal of poorer quality is passed on to the metals branches, dampening gains in productivity in those branches.

III. Causes of the Decline in Soviet Industrial Growth

A. INTRODUCTION

From the estimates of industrial growth and input and factor productivity trends presented earlier, it seems apparent that growth in industrial output declined moderately but steadily from 1950 to 1965 and that the reasons for the decline varied over the period. Through 1955 the effect on industrial growth of some decline in the rate of growth of inputs into industry was more than offset by a rise in the rate of increase of factor productivity. From 1956 to 1961 the annual percentage growth in inputs fell so drastically that higher rates of gain in factor productivity could not stave off continuing decline in the rate of growth of industrial production. After 1961, however, as the rate of increase of industrial inputs rebounded sharply, the rate of growth in factor productivity fell so low that the U.S.S.R. sustained a further drop in the rate of growth of industrial output.

Before discussing some of the possible causes for these changes, it would be appropriate to recapitulate some of the primary findings concerning these trends. Following are the highlights for industry as a whole:

(1) The rate of increase in industrial output declined after 1955 from an average annual rate of growth of about 11 percent in 1951–55 to 9 percent in 1956–61 and to 7 percent in 1962–65.

(2) Total employment and capital stock grew at a relatively steady pace—2.4 to 5.4 percent a year for increases in the labor force and a steady annual net increase of 11 to 12 percent in reproducible assets.

(3) Total man-hours worked annually between 1955 and 1961 remained practically unchanged as the growth in the labor force was offset by a gradual 7-hour reduction in the scheduled workweek and by the increase in days off for vacations and sickness.

(4) The reduction in man-hours worked led to a halving of the annual increment in aggregate inputs after 1955—roughly from an average of 6.4 percent in 1951–55 to 3.3 percent in 1956–61.

(5) Meanwhile, the rate of increase in overall factor productivity trended upward throughout the 1950's, reached a peak in 1956–58, declined slightly in 1959–61, and dropped sharply in 1962–65.

B. LONGRUN FACTORS AFFECTING INDUSTRIAL GROWTH DURING THE 1950'S

Although many developments of the last 15 years contributed to the trends in output and productivity, two factors during the postwar period tended to bolster factor productivity gains and, therefore, growth in industrial output. Yet, the steam imparted to industrial growth by both factors apparently diminished by the end of the 1950's.

During 1946–50, rapid recovery from wartime disruption in the U.S.S.R. was accompanied by high rates of growth in industrial production and factor productivity as in most other war-damaged nations. Raymond P. Powell's computations for this period suggest average annual rates of increase in factor productivity in the U.S.S.R. of 7 to 8 percent.[13] In addition to the usual gains from reconstruction, important gains were achieved in the adoption of advanced technology as investment in new industrial plant and equipment proceeded. Soviet industrial technology was far behind that of the West before World War II, and further Western advances during the war created more opportunities for borrowing and catching up. Moreover, as an indirect result of the war, there was an opportunity to import new production techniques from the West through wartime contacts with the Allies, lend-lease aid, postwar reparations from Germany and Eastern Europe, and the use of captive services of engineers, designers, and scientists from the occupied areas. As the Soviet authorities reduced the gap between their own and Western technology, a slowdown in productivity gains could be anticipated. But this catching-up phase certainly had not ended by the early 1950's, and important economies in inputs based on catching up probably were being made until at least the middle of the decade. In this overall view of the postwar record the rapid deceleration in growth in factor productivity in 1951–53 appears as a temporary aberration. The most important reason for the abrupt decline appears to have been the rapid step-up in armaments production during the Korean War. The disruptions attending the acceleration of industrial support to the military establishment, especially in machine building, probably restricted the secular increase that would have ensued under normal conditions.

It is doubtful that much of this improved technology is reflected in the indexes of capital stock used in this paper. Therefore, if the

[13] Output and input series were computed by Powell with alternative ruble price weights, and the results differed significantly. The rates of factor productivity increases cited above were based on the use of 1950 prices (Powell, op. cit., p. 172).

U.S.S.R. was operating within the frontier of technological knowledge and was "borrowing" technology, the results would be reflected in the growth of factor productivity. As the frontier is approached, the potential for such borrowing diminishes and the rate of growth of Soviet technological progress (as well as output and factor productivity) should fall off.

Another factor related to input quality operated to hold up the rate of industrial growth during the 1950's. The educational attainment of the labor force seems to have increased at a rapid rate at least through 1959 but then the growth slowed down. This judgment relies on the belief that calculations of the stock of human capital in the Soviet labor force prepared by Nicholas DeWitt for 1959 and earlier years and carried forward to 1965 also correctly describe the industrial labor force.[14] The results of these calculations are summarized in the following tabulation.

Average annual increases in human capital

[In percent]

Years	Total human capital in labor force	Human capital per worker
1951–59	7.1	4.9
1960–62	4.6	3.1
1963–64	4.6	2.8

In these estimates the increase in human capital represents the amount of accumulated investment embodied in the formal education of that labor force. The total of this investment [15] at any given time can be thought of as the value of the stock of human capital gainfully occupied in economic activity. Large investments in the schooling of its potential labor supply have resulted in a phenomenal increase in the formation of human capital embodied in the average employed person in the U.S.S.R. For example, the total stock of human capital increased at an average annual rate of 7.1 percent during 1951–59 compared with an average annual increase of 2.1 percent in the total number of persons gainfully occupied in economic activity. Thus there was nearly a 5-percent annual rate of increase in total investment per worker through the attainment of additional education.[16]

The decline in the rate of growth in human capital per worker is more relevant for the course of output and factor productivity in industry. Unless industry was able to insure an offsetting increase

[14] Nicholas DeWitt, "Costs and Returns to Education in the U.S.S.R.," Cambridge, Mass., 1962, pp. 136, 273.

[15] Including the accumulated cost of educating the person to the highest grade level attained plus the value of output that the economy foregoes by not having him in productive employment during the period of his schooling.

[16] In his study of U.S. economic growth, Edward Denison estimated that nearly one-fourth of the total growth in national income during 1929–57 was accounted for by an increase in the average educational attainment of the labor force (op. cit., p. 73).

in its share of the better educated, it too must have faced an erosion in the rate of increase of the quality of its work force—at least as measured by educational attainment.[17] An additional factor that tended to enhance the quality of the civilian labor force in 1956–59—a reduction in the size of the armed forces—failed to contribute significantly in the recent period. The total net reduction in the armed forces of 2.2 million in 1956–59 does not seem to have continued on anything like the same scale. Available evidence suggests that, because of in-service training, the skill level of ex-servicemen is above that of workers with comparable formal education. In contrast, the growth of the employed labor force in 1959–65 included a rising share of relatively inexperienced teenagers and housewives.

While these two factors related to the quality of capital and labor services were at work, another development was making it more difficult for the Soviets to keep up the rate of growth of industrial production. In every one of the nine branches of industry examined as well as in industry as a whole, the capital-labor ratio was rising sharply. It was not possible to push additional labor into industry as fast as capital stock was increasing. Given less than perfect substitutability of capital for labor, this should have meant that increasing quantities of net investment were required with a given increase in man-hours to get the same increase in combined labor and capital inputs.

Another potential factor tending to depress factor productivity and output gains applies to the extractive industries. In ferrous and nonferrous metals the large investments devoted to mining and treating low-grade ores retard productivity and output gains.[18] There simply is not a sufficient supply of ores of equal quality available for exploitation, particularly when output is expanding so rapidly.

C. SPURT IN FACTOR PRODUCTIVITY, 1954–58

Despite the longrun factors tending to pull down the growth in output and factor productivity during the 1950's, factor productivity gains clearly surged upward in 1954–55 and 1956–58. It is tempting to explain part of this spurt by the political history of the time. The death of Stalin and the end of the Korean hostilities may have stimulated the growth of factor productivity. The simple relaxation of terror and the lifting of the more heavy-handed controls probably fostered some of the productivity gains revealed in the statistics. Factor productivity increased from 4.1 percent annually in 1951–53 to 5.1 percent in 1954–55 and 5.7 percent in 1956–58.

Then, too, the reorganization of 1957 to the *sovnarkhoz* system may have given a temporary boost to efficiency by correcting a few of the

[17] B. N. Mikhalevskiy in Ekonomika i matematicheskiye metody, No. 6, 1965, p. 893, estimates that for the U.S.S.R. the rate of increase in the net value of labor power, weighted by qualifications of the workers, was 12.3 percent per year during 1952–59 and 6.8 percent per year during 1960–63.

[18] See, for example, the article by M. Kandyba and V. Panasenko in Planovoye khozyaystvo, No. 12, December 1963, pp. 58–62.

most glaring weaknesses in the management of industry. Despite the abuse heaped on the *sovnarkhozy*, the old ministerial system probably had become so fossilized that any shakeup might have helped efficiency.

The increase in the rate of growth of factor productivity which kept up the growth in industrial production after 1955 also coincided with the reduction in the length of the workweek. The regime placed particular emphasis on tying both the reduction in hours and the wage reform to the uncovering of intra-enterprise reserves. This pressure undoubtedly succeeded to some extent, but it is important to note that any such gains in efficiency were by their nature one-time gains. Internal reserves insofar as they represented inefficiencies in the organization of production could not be "uncovered" repeatedly.

In this somewhat eclectic survey of possible reasons for the increase in factor productivity growth in the 1950's, the change in the structure of industrial investment is worth mentioning. The capital stock indexes used in this paper assume that the marginal productivity of additional capital in the form of buildings and structures is equal to that of equipment. This is probably untrue; at least the Soviets believe it is not so. They have stressed the importance of raising the equipment portion of investment as a means of reversing the unfavorable trend in the output-capital ratio.[19] From 1950 to 1955 the share of equipment in industrial investment fell from 40 percent to 33 percent. It then rose to 37 percent in 1956 and to an average of 40 percent during 1957–1960.[20]

Finally, the decline in the size of the armed forces announced by Khrushchev after 1955 may have been accompanied by a reduction in defense expenditures for a few years at least. In any case the effect would have been to dampen the competition for skilled scientific and technical civilian manpower and to release trained manpower from military service.

D. DECELERATION IN GROWTH OF FACTOR PRODUCTIVITY AFTER 1959

The highest rate of increase in factor productivity in industry during the 15-year period 1951–65 came in 1959—an increase of 6.4 percent. This peak was followed by a rapid deceleration to 4.9 and 5.0 percent in 1960 and 1961, 3.0 percent in 1962, 1.4 percent in 1963, 0.9 percent in 1964, and 1.4 percent in 1965. As suggested above, some part of this decline must have been a normal aftermath of the postwar recovery surge and hence is likely to be permanent. However, recent developments determined the timing and abruptness of the decline and contributed substantially to its magnitude. The effect of these factors is either temporary or at least subject to change in the sense that policy decisions of the Soviet Government could reverse or offset them.

[19] L. Gatovskiy argues that this is a key factor in stimulating technical progress. (Ekonomicheskaya gazeta, No. 48, December 1963, p. 5.)

[20] V. P. Krasovskiy and A. S. Tolkachev, "Struktura kapital'nykh vlozhenyy SSSR i SShA," Moscow, 1965, p. 83.

The abruptness of the decline in gains in factor productivity in 1962–65, after the reduction in the workweek had been completed, raises the question of the impact of declining man-hours per worker on productivity. The earlier discussion of factor productivity calculated with employment rather than man-hours as the labor input suggested that in the absence of a reduction in the workweek the decline might have begun in 1960 instead of 1962 and thus might have been less abrupt. Second, to the extent that enterprise managers were successful in increasing productivity during 1956–59, they may have temporarily reduced opportunities for further increases after 1959.

A number of other recent developments in the use of labor and capital could have contributed to the decline in annual growth of factor productivity, as follows:

(*a*) During 1960–63 there was a significant slowdown in the growth of new investment in industry as a consequence, perhaps, of an increase in defense and space expenditures or simply the much discussed problems on the construction front. In the face of this decline in investment growth, industrial capital stock continued to rise with undiminished vigor. A comparison of investment (less the change in unfinished construction) with the change in capital stock in industry indicates that the Soviets may have reduced the rate of retirement of old capital assets by more than one-half after 1959.[21]

In order to maintain old plant and equipment, capital repairs for the economy (and presumably for industry) have accelerated, growing at a planned average rate of 11.8 percent in 1960–63 compared with 5.3 percent in 1956–59.[22] The failure to introduce new plant and equipment into production at previous rates of growth probably has been a factor in the reduced growth of factor productivity. Old equipment that has been overhauled plainly does not introduce new technology in the way that brand-new equipment can and usually does.[23]

(*b*) Even in the branches of industry where gross and net capital formation have accelerated since 1959, the productivity performance has been poor. In the chemical industry, for example, factor productivity has actually declined. Evidence from Soviet publications and the observations of foreign visitors suggest abnormally low operating

[21] From an average implicit rate of retirement of 4.4 percent in 1956–59 to 2.0 percent in 1960–64. The procedure is to subtract the estimated annual increments in capital stock from annual gross investments adjusted for changes in unfinished construction and then to divide the remainder by the capital stock at the beginning of the year. Although the stock figures are only estimates and the comparability of the investment and stock series is not certain, the major data problem is the lack of a series for unfinished construction before 1958. Thus, gross additions probably are abnormally high. Nevertheless, unfinished construction would have had to increase at far above the amounts recorded during 1958–64 to prevent an increase in the implicit retirement rate.

[22] Based on data on centralized financing of capital repair in the national economy. Values in current prices have been deflated roughly by a cost index giving equal weight to the official price index for MBMW output and an index of average annual earnings of wage workers in Soviet industry.

[23] Various Soviet writers have complained of the deadening effect on technological progress of excessive dependence on repairs and maintenance instead of replacement with new equipment. See for example, L. Gatovskiy, op. cit., p. 6, and S. Kamnitzer, Voprosy ekonomiki, No. 8, August 1965, pp. 10–11.

efficiency in newly constructed enterprises, especially in chemical plants incorporating new technology. Thus, much of the sharp decline in productivity may be related to difficulties in assimilating the huge chunks of new capacity that embody technology relatively new to the Soviet scene. This failure to digest new technology appears to be due in part to poor design and incompetent assembly and installation work and in part to the lack of trained operating personnel.[24]

This performance appears to be the byproduct of the general trend toward a more complex and sophisticated industrial sector. The impact of these departures from the old paths of development may be seen in the relation of factor productivity gains to increases in capital stock in industry and the branches of industry. It would be expected that rapid increases in capital stock would tend to favor productivity gains through the medium of "embodied technology." Yet the association of factor productivity growth with growth in capital stock in Soviet industry has been low or even negative.[25]

(*c*) In some branches of industry, notably the light and food branches, the poor output and productivity records of recent years are certainly explained in large part by a shortage of raw materials caused by harvest failures. In light industry, changing consumer preferences have forced changes in the output mix that may have cut output and productivity gains temporarily.

(*d*) A factor that may have contributed to the recent decline in growth in factor productivity is the significant dropoff in the contribution of increased education toward raising the quality of the labor force. The extent of this decline and its potential importance was discussed above.

(*e*) There is another plausible reason for the paradox of rapid formation of new capital associated with the deceleration of the growth of productivity. It seems clear that the Soviets have spent increasingly large sums since the mid-1950's on military and space hardware and on military research and development. The rates of growth of civilian machinery output and investment in machinery and equipment cannot be reconciled with the announced rates of growth of machine building and metalworking output unless there have also been substantial increases in the production of military machinery.

This expansion probably has been particularly large in programs—for example, advanced weapons and space—that directly compete

[24] See Kamnitzer, op. cit., for a discussion of the problems of introducing unfamiliar technology. In 1962, more than 80 percent of new workers in the chemical industry had no formal training or had received only short on-the-job training. (G. Zelenko, Pravda, Feb. 3, 1964.) One Soviet source estimated that the graduation of chemical specialists had to rise from 10,000–12,000 in 1961–62 to 50,000–60,000 in 1964–65 to meet the needs of the chemical industry. (Voprosy ekonomiki, No. 12, December 1963, p. 13.)

[25] The Kendall rank correlation coefficients for percentage increases in capital stock and factor productivity for the nine branches of industry are −0.25 for 1951–64, −0.22 for 1951–58, and −0.28 for 1959–64. However, there is about one chance in five that correlations of this magnitude would occur even if the variables were not related. When, for each branch, five subperiods are ranked by average annual growth in capital stock and factor productivity, there are two positive Kendall rank correlations, two coefficients of zero, and five negative coefficients.

with those investment needs of industry requiring complex machinery and highly skilled scientific and technical manpower. Thus a diversion, in large quantities, of highly specialized and scarce resources to military and space programs may be of major importance in explaining the recent decline in factor productivity in industry.[26]

E. PROSPECTS FOR GROWTH IN INDUSTRIAL OUTPUT IN THE NEW 5-YEAR PLAN (1966–70)

Whether the recent slump in the growth of factor productivity will continue, level off, or reverse itself has, of course, particular importance for future Soviet development. It is unlikely that the U.S.S.R. can continue to increase inputs into industry at the rate of the early and mid-1950's. The well-publicized discussions in the U.S.S.R. of incentives, efficiency, and planning techniques testify to the official concern over this question.

Leonid Brezhnev in his address to the 23d Congress of the Communist Party noted the official disappointment over industrial performance. He also stated his belief that the September 1965 program for economic reform in industry had prepared the way for restoring higher rates of growth in output and productivity in industry.[27] This belief is imbedded in the new 5-year plan (1966–70) which calls for a 47–50 percent rise in industrial output and a 33–35 percent increase in labor productivity by 1970.[28]

The planned average annual increase in industrial output of 8.0–8.4 percent during 1966–70 seems cautious enough. It would not bring back the rates of increase estimated for 1959–61 in this paper, much less those claimed by the Soviets. Nonetheless, a tentative calculation based on the labor productivity goals and the incomplete plans for industrial investment shows that even this modest proposal depends for its success on a sharp recovery in the growth of factor productivity.[29] From an average annual increase of 1.6 percent in 1962–65, the rate of increase of factor productivity would have to bounce back to 4.1 percent during 1966–70.[30] This implied rate of gain in productivity

[26] The announced index of MBMW output for 1964 is 700 (1950=100); the index used in this paper is 485. Yet the index for investment in machinery and equipment in the economy is 478, and this includes net imports which have been sizable in recent years. Although output of consumer durables has been rising much more rapidly than investment in machinery and equipment, the relatively small weight of consumer durables in total output could not account for the apparently high rates of increase in MBMW production unless military output was also increasing at a high rate.

[27] Pravda, Mar. 30, 1966, p. 5.

[28] Izvestiya, Feb. 20, 1966, p. 2.

[29] The planned annual increase in labor productivity in industry amounts to 5.9–6.2 percent per year in 1966–70 compared to 4.7 percent in 1961–65 and 6.6 percent in 1956–60.

[30] Assuming a weight of 0.72 for labor and 0.28 for capital and a 48½ percent increase in industrial output during 1966–70 combined with an average annual increase of 9½ percent in capital stock and 1.9 percent for man-hours. The estimate of increase in man-hours relies on the announced goals for labor productivity.

would almost recapture the successes of 1960–61, when the average annual rate of growth of factor productivity leveled out at 5 percent per year before plunging downward.

It would not be surprising to see productivity rebound to some extent. The performance of Soviet agriculture should improve—to the benefit of the light and food branches—and the stabilization of the workweek should also help. To the extent that the pressures surrounding the introduction of a shorter workweek "borrowed" efficiency gains from future periods, productivity gains in the recent past have been depressed unnaturally. Still no convincing appraisal of the realism of the new 5-year plan in industry can be made without a knowledge of the probable effects of the managerial reform in industry, particularly over the next 3 or 4 years when the reform is being introduced. Such a judgment is far beyond the bounds of this paper.

Appendix A. Derivation of the Index Formula Used in Calculating Factor Productivity

The index formulas or the production functions used to aggregate inputs are of two kinds: a geometric function of the Cobb-Douglas type and an arithmetic function. The geometric function is of the form $P_t = cL_t^a K_t^b$ and the arithmetic function is of the form $P_t = e\ (w_o L_t + r_o K_t)$ where

P_t = predicted output in year t resulting solely from increase in inputs
L_t and K_t = labor and capital inputs in year t
a and b = labor and capital coefficients
c, e = multiplicative constants
w_o and r_o = price of labor and capital inputs in the base period
$a + b$ = 1

The geometric function is used predominantly in the calculation of factor productivity in this paper; the results of using the arithmetic function are shown only for all industry. If it is assumed that both labor and capital inputs are paid the value of their marginal product in the base period, it can be shown that the values of a and b for the geometric function are equal to their proportionate share of value added in the given sector of production in the base period. The geometric function can be converted into a ratio of predicted output:

$$\frac{P_t}{P_o} = \frac{L_t^a K_t^b}{L_o^a K_o^b} = \left(\frac{L_t}{L_o}\right)^a \left(\frac{K_t}{K_o}\right)^b$$

Similarly the arithmetic function can be transformed into a ratio of predicted output with coefficients a and b equal to those used in the geometric function:

$$\frac{P_t}{P_o}=a\frac{L_t}{L_o}+b\frac{K_t}{K_o}$$

The shares of labor and capital in total value added (and therefore values for the coefficients a and b) for all industry and for the branches of industry must be contrived. In the calculation the aim is to approximate the relative marginal products of labor and capital.

First, average annual earnings of workers and employees together with social insurance deductions are taken to reflect the values of the marginal product of labor for industry as a whole and for the various branches of industry. This assumption has been implicit in other studies and is adopted here in the belief that the degree of mobility in the Soviet labor market is sufficient to make relative wages correspond to relative marginal productivity. The average annual earnings multiplied by the number of workers and employees is taken as the absolute share of labor inputs in total value added. Two years, 1950 and 1960, are used as base years in order to make it possible to appraise the effect on the production functions of changing input mixes, relative factor earnings, and technologies employed.

The calculation of return to capital requires that a rate of return be applied to estimates of average undepreciated fixed capital stock on hand in industry and the industrial branches in 1950 and 1960, valued in 1955 prices. Undepreciated or gross fixed capital stock is used in the calculation in the belief that the services of capital stock do not decline through time nearly as rapidly as the application of straight-line depreciation would imply. Therefore, when capital stock is increasing, the deduction, for example, of straight-line depreciation from gross capital stock overstates the loss in its input efficiency. On the other hand, the additions to capital stock tend to be more productive than the stock going out of service, so that in this respect a gross capital stock series understates the trend in capital services.

The rate of return itself is a combination of interest charges and depreciation charges. In the absence of any knowledge as to what would be a correct interest rate, rates of 8 percent or 13 percent are employed.[31] The depreciation charges for each industrial sector are the amortization rates recently introduced in the U.S.S.R. for fixed assets. This gives a rate of return of 11 to 15 percent using an interest rate of 8 percent and a rate of return of 16 to 20 percent using an interest rate of 13 percent. The steps taken in the computation of these production function coefficients are summarized in Table 6. Although every step in the derivation of these coefficients involves some estimation, the wide range in the value of the coefficients derived gives some expression to the underlying uncertainties. In calculating factor productivity indexes, all of these coefficients are used because there is no good reason for preferring one to another.

[31] See footnote 7, above.

TABLE 6.—*U.S.S.R.: Derivation of estimated production function coefficients*

Branch	Base year	Employment of workers [1] (thousands of persons)	Ratio of workers and employees to workers [2] (thousands of persons)	Employment of workers and employees [3] (thousands of persons)	Average annual earnings [4]	Social insurance deductions as share of wage fund [5] (percent)	Labor costs [6] (billions of new rubles)	Productive fixed capital [7] (billions of new rubles)	Amortization charge [8] (percent)	Capital cost		Total labor and capital cost		Labor coefficient [13]	
										Billions of rubles [9]	Billions of rubles [10]	Billions of rubles [11]	Billions of rubles [12]	Col. 6 divided by col. 11	Col. 6 divided by col. 12
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Industry	1950	12,289	(1.251)	15,374	866	6.8	14.22	29.10	4.14	3.53	4.99	17.75	19.21	0.80	0.74
	1960	18,574	(1.210)	22,289	1,096	7.0	26.14	85.09	4.14	10.33	14.58	36.47	40.72	.72	.64
Ferrous metals	1950	604	(1.232)	744	1,132	7.9	.91	2.90	3.51	.33	.48	1.24	1.39	.73	.65
	1960	886	(1.182)	1,047	1,393	7.9	1.57	8.24	3.51	.95	1.36	2.52	2.93	.62	.54
Coal	1950	732	(1.209)	855	1,465	9.0	1.41	2.61	6.59	.38	.51	1.79	1.92	.79	.73
	1960	1,031	(1.160)	1,196	2,036	9.0	2.65	7.27	6.59	1.06	1.42	3.71	4.07	.71	.65
Petroleum products and natural gas	1950	92	(1.380)	127	1,028	8.4	.14	1.61	6.59	.23	.32	.37	.46	.38	.30
	1960	148	(1.324)	196	1,235	8.4	.26	6.09	6.59	.89	1.19	1.15	1.45	.23	.18
Machine building and metalworking	1950	3,314	(1.305)	4,325	915	7.5	4.25	7.74	3.71	.91	1.29	5.16	5.54	.82	.77
	1960	5,655	1.252	7,080	1,102	7.5	8.39	16.96	3.71	1.99	2.83	10.38	11.22	.81	.75
Construction materials	1950	567	(1.189)	674	763	6.1	.55	.75	4.45	.09	.13	.64	.68	.86	.81
	1960	1,310	(1.140)	1,493	1,033	6.1	1.64	4.70	4.45	.59	.82	2.23	2.46	.74	.67
Light	1950	2,267	(1.204)	2,729	639	6.8	1.86	1.70	3.60	.20	.28	2.06	2.14	.90	.87
	1960	3,371	(1.155)	3,894	818	6.8	3.40	3.79	3.60	.44	.63	3.84	4.03	.89	.84
Food	1950	1,320	(1.283)	1,694	582	6.8	1.05	3.19	3.64	.37	.53	1.42	1.58	.74	.66
	1960	1,743	(1.231)	2,146	821	6.8	1.88	7.70	3.64	.90	1.28	2.78	3.16	.68	.59
Chemicals	1950	365	(1.318)	481	887	8.4	.46	1.33	3.54	.15	.22	.61	.68	.75	.68
	1960	584	1.265	739	1,135	8.4	.91	4.25	3.54	.49	.70	1.40	1.61	.65	.57
Forest products	1950	----------	----------	2,779	734	4.7	2.14	2.06	5.83	.28	.39	2.42	2.53	.88	.85
	1960	----------	----------	2,598	1,023	4.7	2.78	4.98	5.83	.69	.94	3.47	3.72	.80	.74

[1] From table 7, appendix B.

[2] These ratios for all industry in 1950 and in 1960 and for 1960 in the ferrous metals, coal, petroleum products and natural gas, construction materials, light, and food branches are derived from reported numbers of industrial production personnel and wageworkers. U.S.S.R., Central Statistical Administration, *Promyshlennost' SSSR*, Moscow, 1964, pp. 85, 158, 186, 314, 354, and 424. The 1960 ratio for MBMW is the ratio for MBMW in the R.S.F.S.R. U.S.S.R. Central Statistical Administration, *Promyshlennost' RSFSR*, Moscow, 1961, p. 36. The 1960 ratio for chemicals is based on the ratio for 1955 as reported in N. N. Nekrasov, *Ekonomika khimicheskoy promyshlennosti*, Moscow, 1959, p. 331. The ratio for 1955 was moved forward to 1960 on the basis of the change in the ratios for industry as a whole. All of the branch ratios for 1950 are equal to the 1960 ratios adjusted by the change in the ratio for industry as a whole.

[3] Number of workers and employees are either given in Soviet statistical handbooks or are estimated by multiplying the number of workers in column 1 by the ratios in column 2. (See f.n. 2., above). The figure for workers and employees in forest products for 1960 is from *Promyshlennost' SSSR*, *op. cit.*, p. 291, and the 1950 figure is derived from the 1960 figure and the index of employment in Table 7.

[4] Average annual earnings in industry and the branches of industry are estimated from the following sources: *Earnings in Industry*—U.S.S.R., Central statistical Administration, *Narodnoye khozyaystvo S.S.S.R. v 1964 godu*, Moscow, 1965, p. 555; *Finansy SSSR*, no 7, 1962, p. 5; *Ekonomicheskaya gazeta*, April 23, 1962, p. 91; L. A. Blyakhman *Proizvoditel'nost' i oplata truda v period razvernutogo stroitel' stva kommunizma*, Leningrad, 1964, p. 313, 320; D. N. Karpukhin, *Sootnosheniye rosta proizvoditel' nosti truda i zarabotnoy platy*. Moscow, 1963, p. 168. *Earnings in branches of industry—Trud i zarabotnaya plata*, no 10, 1961, p. 24; Karpukhin, *op. cit.*, p. 168; I. A. Orlovskiy and G. P. Sergeyeva, *Sootnosheniye rosta proizvoditel'nosti truda i zarabotnoy platy v promyshlennosti SSSR*, Moscow, 1961, pp. 44, 51; A. G. Aganbegyan and V. F. Mayer, *Zarabotnaya plata v SSSR*, Moscow, 1959, p. 187; Blyakhman, *op. cit.*, p. 322. No increase in wages of workers in construction materials between 1959 and 1960 has been reported, so it was assumed to be 2 percent. In both 1950 and 1960 the ratio of earnings of workers and employees to earnings of workers was estimated from reported distributions of employees given in various statistical handbooks and from earnings ratios for various categories reported in Orlovskiy and Sergeyeva, *op. cit.*, p. 53; Aganbegyan and Mayer, *op. cit.*, pp. 201–202; V. N. Yagodkin, *Osnovnyye zakonomernosti vosproizvodstva robochiy sili v period na razvernutogo stroitel'stvo kommunizma*, Moscow, 1965, p. 133; and *Sotsialisticheskiy trud*, no 9, 1960, pp. 6–7.

[5] Social insurance deduction rates for the branches are taken from V. Krulikovskaya, et. al., *Planirovaniye byudzheta gosudarstvennogo sotsial'nogo strakhovaniya*, Moscow, 1959, pp. 17–18. The rate for all industry is a weighted average of the branch rates.

[6] (Column 3 times column 4) + column 5 (column 3 times column 4).

[7] Capital stock 1 Jan. 1960 (as reported in *Narodnoye khozyaystvo SSSR v 1959 godu*, pp. 67–68) has been converted to an average annual basis for 1950 and 1960 by the indexes of capital stock presented in Table 8.

[8] "Actual amortization" (excluding that for capital repair) according to the new norms introduced on Jan. 1, 1963. U.S.S.R. Academy of Sciences, Institute of Economics, *Teoriya amortizatsii i technicheskiy progress*, Moscow, 1965, p. 155. The rate given for the fuel industry was used both for coal and for petroleum products and natural gas.

[9] Column 7 times the sum of column 8 and an 8-percent interest charge on capital stock.

[10] Column 7 times the sum of column 8 and a 13-percent interest charge on capital stock.

[11] Column 6 plus column 9.

[12] Column 6 plus column 10.

[13] The capital coefficients for each sector are equal to 1 minus the value of the labor coefficients.

Appendix B. Derivation of Indexes of Labor Inputs

1. Description of Indexes of Labor Inputs

The indexes of labor inputs rely on published Soviet data on employment of wageworkers in industry and by branch of industry. Although it would be better to use data on all wage and salary workers involved in the production process, such data are available through time only for industry as a whole.[32] Moreover the ratio of wageworkers to wage and salary workers in industry has not changed so much as to cast doubt on the use of labor inputs series based on employment of wageworkers as representative of total employment trends. An employment index derived from labor productivity data was used for all years for the forest products industry. Alternative indexes of labor inputs reflecting man-hours worked are computed by applying branch indexes of hours worked per year per man to the employment indexes. The indexes of the length of the workday and the number of days worked per year are based on data reported in the Soviet yearbooks and in articles reporting on the progress of the reduction of hours in industry.

The problem of matching the coverage of inputs against the coverage of outputs appears in the case of the labor inputs indexes. Conceptually the output indexes cover all output of a given classification whether produced in the given branch, in other branches, or in nonindustrial sectors.[33] Reported branch employment data, however, are on an enterprise basis, so that workers in a given plant are classified according to the character of its primary output. Moreover, they exclude industrial employment in industrial cooperatives or in agriculture. In contrast, inputs series derived from labor productivity and gross output data are based on employment which includes in some cases all industrial production personnel rather than just "workers" and also workers in those producer cooperatives classified under industry. For some branches, moreover, labor productivity is calculated only for a major segment of the branch, such as coal extraction and timber cutting within the coal and logging branches. A particularly difficult problem results from the Soviet transfer of industrial cooperatives into state industry in 1956 and in 1960. As the reported employment data include these transferees, the reported data must be adjusted to prevent an overstatement of the growth in industry and branch employment.

In spite of the adjustments applied to the data, the mismatching of labor inputs and outputs resulting from differing coverage probably results in an understatement of the growth in factor productivity. This follows from the belief that there has been a trend toward specialization in industrial production and that employment of an industrial character outside of industry has not been increasing as rapidly as employment in industry. For particular branches of industry the net effect of using employment classified on an establishment basis rather than on a product basis to measure labor inputs is difficult to gauge. Nevertheless, it should be remembered that branches vary greatly in terms of the extent to which they specialize in production of their primary product and the proportion of total output of their primary product that they account for. For this reason, interbranch comparisons of factor productivity based on the sort of labor inputs indexes used in this paper must be viewed with caution.

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[32] Wageworkers are the *rabochiye* in Soviet terminology, and the wage and salary workers involved in the production process are industrial-production personnel (*promyshlenno-proizvodstvennyy personal*). The Soviet statistical category *rabochiy* is similar to the U.S. category of production worker, although somewhat more limited in coverage. The Soviet category excludes some custodial personnel and technical personnel normally included in the U.S. concept of production worker.

[33] For example, some chemicals are produced in the ferrous metals branch, and some machine building enterprises produce ferrous metals. In the output indexes this output appears under chemicals and ferrous metals, respectively, rather than under ferrous metals and machine building.

TABLE 7.—*USSR: Employment and indexes of labor services in industry, by branch, selected years, 1950–64*

Branch	1950	1952	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Industry:													
Employment (thousand wageworkers [1]):													
Reported	11,308	12,474	13,179	14,281	15,226	15,760	16,279	16,793	18,574	19,548	20,176	20,760	21,435
Estimated industrial cooperative component	981	1,133	1,215	1,263	825	675	825	900					
Adjusted	12,289	13,607	14,394	15,544	16,051	16,435	17,104	17,693	18,574	19,548	20,176	20,760	21,435
Indexes of labor services (1950=100):													
Adjusted employment	100.0	110.3	117.1	126.5	130.6	133.7	139.2	144.0	151.1	159.1	164.2	168.9	174.4
Hours worked per year	100.0	99.5	99.3	98.9	96.0	94.1	91.8	89.4	84.8	80.1	79.9	80.2	80.8
Man-hours	100.0	110.1	116.3	125.1	125.4	125.8	127.8	128.7	128.1	127.4	131.2	135.5	140.9
Ferrous metals:													
Employment (thousand wageworkers):													
Reported	604	675	706	742	751	764	812	841	886	923	947	979	1,009
Indexes of labor services (1950=100):													
Reported employment	100.0	111.8	116.9	122.8	124.3	126.5	134.4	139.2	146.7	152.8	156.8	162.1	167.1
Hours worked per year	100.0	99.5	99.3	98.9	96.0	91.6	85.4	81.8	81.4	80.1	79.9	80.2	80.8
Man-hours	100.0	111.2	116.1	121.4	119.3	115.9	114.8	113.9	119.4	122.4	125.3	130.0	135.0
Coal:													
Employment (thousand wageworkers):													
Reported	732	763	793	897	968	1,021	1,071	1,074	1,031	1,005	996	986	988
Indexes of labor services (1950=100):													
Reported employment	100.0	104.2	108.3	122.5	132.2	139.5	146.3	146.7	140.8	137.3	136.1	134.7	135.0
Hours worked per year	100.0	99.5	99.3	98.9	96.0	91.5	85.6	80.0	75.5	72.6	72.3	72.6	73.2
Man-hours	100.0	103.7	107.5	121.2	126.9	127.6	125.2	117.4	106.3	99.7	98.4	97.8	98.8
Petroleum products and natural gas:													
Employment (thousand wageworkers):													
Reported	92.0	103.0	109.0	124.0	127.0	130.0	140.0	143.0	148.0	157.0	154.0	154.0	(156.0)
Indexes of labor services (1950=100):													
Reported employment	100.0	112.0	118.5	134.8	138.0	141.3	152.2	155.4	160.9	170.7	167.4	167.4	(169.6)
Hours worked per year	100.0	99.5	99.3	98.9	96.0	94.4	93.6	90.6	84.7	80.4	80.1	80.5	81.1
Man-hours	100.0	111.4	117.7	133.3	132.5	133.4	142.5	140.8	136.3	137.2	134.1	134.8	(137.5)

See footnote at end of table, p. 309.

TABLE 7.—*USSR: Employment and indexes of labor services in industry, by branch, selected years, 1950–64*—Continued

Branch	1950	1952	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Machine building and metalworking:													
Employment (thousand wage-workers):													
Reported	3,216.0	3,581.0	3,837.0	4,256.0	4,539.0	4,736.0	4,932.0	5,149.0	5,655.0	6,207.0	6,586.0	6,938.0	7,249.0
Estimated industrial cooperative component	98.0	113.0	122.0	126.0	82.0	68.0	82.0	90.0					
Adjusted	3,314.0	3,694.0	3,959.0	4,382.0	4,621.0	4,804.0	5,014.0	5,239.0	5,655.0	6,207.0	6,586.0	6,938.0	7,249.0
Indexes of labor services (1950=100):													
Adjusted employment	100.0	111.5	119.5	132.2	139.4	145.0	151.3	158.1	170.6	187.3	198.7	209.4	218.7
Hours worked per year	100.0	99.5	99.3	98.9	96.0	94.4	92.8	89.8	84.8	80.6	80.3	80.7	81.3
Man-hours	100.0	110.9	118.7	130.7	133.8	136.9	140.4	142.0	144.7	151.0	159.6	169.0	177.8
Construction materials:													
Employment (thousand wageworkers):													
Reported	547	649	720	830	838	952	1,072	1,162	1,310	1,375	1,383	1,364	1,365
Estimated industrial cooperative component	20	23	24	25	17	14	17	18					
Adjusted	567	672	744	855	855	966	1,089	1,180	1,310	1,375	1,383	1,364	1,365
Indexes of labor services (1950=100):													
Adjusted employment	100.0	118.5	131.2	150.8	150.8	170.4	192.1	208.1	231.0	242.5	243.9	240.6	240.7
Hours worked per year	100.0	99.5	99.3	98.9	96.0	94.4	92.8	89.8	84.8	80.6	80.3	80.7	81.3
Man-hours	100.0	117.9	130.3	149.1	144.8	160.9	178.3	186.9	195.9	195.5	195.9	194.2	195.7
Light:													
Employment (thousand wageworkers):													
Reported	1,678	1,885	1,975	2,158	2,385	2,467	2,515	2,579	3,371	3,472	3,544	3,550	3,648
Estimated industrial cooperative component	589	680	729	758	495	405	495	540					
Adjusted	2,267	2,565	2,704	2,916	2,880	2,872	3,010	3,119	3,371	3,472	3,544	3,550	3,648
Indexes of labor services (1950=100):													
Adjusted employment	100.0	113.1	119.3	128.6	127.0	126.7	132.8	137.6	148.7	153.2	156.3	156.6	160.9
Hours worked per year	100.0	99.5	99.3	98.9	96.0	94.4	93.6	93.0	87.1	80.5	80.2	80.6	81.2
Man-hours	100.0	112.5	118.5	127.2	121.9	119.6	124.3	128.0	129.5	123.3	125.4	126.2	130.6

Food:													
Employment (thousand wageworkers):													
Reported	1,232	1,332	1,398	1,478	1,579	1,645	1,662	1,688	1,743	1,827	1,844	1,919	1,975
Estimated industrial cooperative component	88	102	109	114	74	61	74	81					
Adjusted	1,320	1,434	1,507	1,592	1,653	1,706	1,736	1,769	1,743	1,827	1,844	1,919	1,975
Indexes of labor services (1950=100):													
Adjusted employment	100.0	108.6	114.2	120.6	125.2	129.2	131.5	134.0	132.0	138.4	139.7	145.4	149.6
Hours worked per year	100.0	99.5	99.3	98.9	96.0	94.5	93.7	93.2	87.3	80.5	80.2	80.6	81.2
Man-hours	100.0	108.1	113.4	119.3	120.2	122.1	123.2	124.9	115.2	111.4	112.0	117.2	121.5
Chemicals:													
Employment (thousand wageworkers):													
Reported	326	373	404	452	469	478	494	521	584	621	705	800	870
Estimated industrial cooperative component	39	45	49	51	33	27	33	36					
Adjusted	365	418	453	503	502	505	527	557	584	(621)	705	800	870
Indexes of labor services (1950=100):													
Adjusted employment	100.0	114.5	124.1	137.8	137.5	138.4	144.4	152.6	160.0	170.1	193.2	219.2	238.4
Hours worked per year	100.0	99.5	99.3	98.9	95.9	94.3	88.5	82.4	81.6	80.8	80.5	80.9	81.5
Man-hours	100.0	113.9	123.2	136.3	131.9	130.5	127.8	125.7	130.6	137.4	155.5	177.3	194.3
Forest products:													
Indexes of labor services (1950=100):													
Estimated employment	100.0	103.1	(2)	107.4	104.4	101.7	99.7	99.3	93.5	93.3	93.3	94.6	94.7
Hours worked per year	100.0	99.5	99.3	98.9	97.5	96.6	94.1	92.6	88.9	82.2	82.0	82.3	82.9
Man-hours	100.0	102.6	(2)	106.2	101.8	98.2	93.8	92.0	83.1	76.7	76.5	77.9	78.5

[1] Wageworkers are the *rabochiye* in Soviet terminology, and the wage and salary workers involved in the production process are industrial-production personnel (*promyshlenno-proizvodstvennyy personal*).

[2] Not available.

Thus the labor inputs indexes available to this paper are imperfect measures of the changes in either employment or man-hours worked. To improve the indexes, more would have to be known about the share in branch output accounted for by workers classified outside the branch and the changes in these proportions over time. Also, it would be desirable to have better information on changes in branch classification and the precise timing of changes both in the length of the scheduled workweek and in hours actually worked.

2. DERIVATION OF EMPLOYMENT INDEXES

The indexes of both employment (or labor force) and man-hours used in the calculation of factor productivity trends are set forth in Table 7. In this section the nature of the employment indexes is discussed. Where absolute employment data appear, they are based first of all on published Soviet sources.[34] The forest products index represents a weighted average of employment series for timber, woodworking, and paper derived from labor productivity and official output data using as weights the absolute employment figures for 1958. For some years, employment in the chemical and construction materials has been interpolated using labor productivity and output data. This was also necessary for the petroleum products and natural gas branch in 1964.[35] It should be noted that the labor productivity series appear to be based on a somewhat different concept of average annual employment. Thus the classification is expanded to include workers in producer cooperatives in employment equivalents (measured in terms of work participation rather than membership).

Because the reported employment data do not include workers in producers cooperatives before 1960, Table 9 shows for all industry and some branches an adjustment to cover these excluded workers. Total employment of workers in industrial producer cooperatives has been estimated by Murray Weitzman and Andrew Elias for 1950–58.[36] Their procedure has been extended to estimate the number of workers in this category in 1959.

It was announced that 500,000 workers and employees were transferred from industrial cooperatives into state industry in 1956 and 1.2 million in 1960. In 1960, of the total, 1 million wageworkers were transferred as part of the liquidation of the industrial cooperatives, including 600,000 into light industry and 100,000 into machine building and metalworking. Of the remainder it is estimated that 120,000 went into state logging enterprises, 90,000 into the food industry, 40,000 into chemicals, and 20,000 into construction materials.[37] The planned distribution of GVO in industrial cooperatives in 1954 was almost precisely the same as the employment distribution in 1960.[38] As the best approximation available, the percentage distribution in 1960 is applied to the other years before 1960. The light and MBMW branches are the only ones likely to be affected materially by any inaccuracies in these estimates.

3. CONVERSION OF EMPLOYMENT INDEXES TO INDEXES OF MAN-HOURS WORKED

Since 1950, hours worked in industry have increased less rapidly because of two factors—a steady reduction in the number of days worked per year and a reduction in the length of the workday after 1955. Both of these trends are represented in the index of hours worked per year as shown in Table 7. Mainly as a result of more generous allowances for holidays and vacation, actual days worked per year were pared by about 4 percent between 1950 and 1964.[39] Because there is no information available by branch, the trend in days worked per year in industry as a whole is assumed to hold for the branches as well. By far the more important cause of the fall in hours worked in recent years, how-

[34] U.S.S.R. Central Statistical Administration: "Narodnoye khozyaystvo v 1961 godu," Moscow, 1962, p. 182; "Narodnoye khozyaystvo v 1962 godu," Moscow, 1963, p. 130; Promyshlennost' SSSR, Moscow, 1964, p. 84–85; "Narodnoye khozyaystvo v 1959 godu," Moscow, 1960, p. 139; "Narodnoye khozyaystvo v 1964 godu," Moscow 1965, p. 136 (hereafter referred to as Narkhoz 19—and Promyshlennost' 1964). Murray S. Weitzman and Andrew Elias, "The Magnitude and Distribution of Civilian Employment in the USSR: 1928–59," Foreign Manpower Research Office, Bureau of the Census, April 1961, p. 71, 72, and 74.

[35] Narkhoz 1958, p. 140, 153–154; Narkhoz 1959: p. 147, 152–154; Narkhoz 1960, p. 226, 231–233; Narkhoz 1961, p. 173, 183–185: Narkhoz 1962, p. 122, p. 132–134; Promyshlennost' 1964, p. 58–61; Narkhoz 1964, p. 139, 166.

[36] Weitzman and Elias, op. cit., Table 5, p. 69 (Reported figure less employment in consumer cooperatives).

[37] Unpublished estimate of the Foreign Demographic Analysis Division, Bureau of the Census.

[38] Frederick A. Leedy, "Producers' Cooperatives in the Soviet Union," Foreign Manpower Research Office, Bureau of the Census, Aug 1958, p. 19.

[39] Vestnik statistiki, no. 2, 1957, p. 91; Narkhoz 1962, p. 131; Promyshlennost' 1964, p. 87; Narkhoz 1964, p. 138.

ever, has been the average transfer to a basic 7-hour day together with additional time off before holidays. Before 1956, the Soviet industrial worker put in an 8-hour day; after 1960, he worked a 7-hour day with six hours on Saturday.

The average length of the scheduled workday for adult workers in Soviet industry and in several industrial branches has been reported for mid-1956, the beginning of 1959, the end of 1959, the end of 1960, and the end of March, 1961. Since that time the reported length of the workday has remained unchanged.[40] In estimating the average annual length of the workday, the following procedure has been used:

1. The actual workday is assumed to be equal in length to the workday.
2. The annual average is taken to be equal to the average length of the workday at midyear. The mid-1959 and mid-1960 estimates are averages of the reported figures for end-of-year 1958, 1959, and 1960.
3. There is a gap in the reported data between the end of 1956 and the end of 1958. Midyear estimates have been interpolated for 1957 and 1958 on the basis of Soviet discussions of the progress of reduction in the length of the workweek.[41] For the years before 1956, it seems legitimate to use the reported figure for mid-1956 for the average length of the workday.
4. Over and above the effect of the shorter workday, the average length of the workweek was shortened in March 1956 by the reduction of preholiday workdays to 6 hours. It is reported that the net effect of this reduction was to cut the length of the average workday by 0.26 hour.[42] Therefore, the average length of the workday for industry and all branches has been reduced by 0.20 hour in 1956 and 0.26 hour thereafter.

The indexes of average length of the workday, adjusted for preholiday reduction of hours, can be derived as explained above for industry and for all of the branches of industry covered in this paper except two. For construction materials the index of the length of the workweek in machine building and metalworking is used because the only information on the progress of reduction of hours in this branch (in production of cement and reinforced concrete) approximated the time-table for machine building and metalworking. The index for the forest products industry is especially tentative. It is assumed that the reduction of hours took place somewhat more slowly than in the paper industry (its smallest component), with most of the changeover occurring in 1960–61. How the reduction of hours was carried out in a seasonal industry like logging is not known.

4. SUMMARY

No exaggerated claims are made concerning the validity of either the employment or the man-hours indexes discussed above. The man-hours indexes for 1957–59 are not grounded as solidly as could be wished, and the possible effect of this on the data should be kept in mind when comparing factor productivity increases of various periods. In addition, the employment data are particularly sensitive to undetected changes in coverage. As discussed above, members of producer cooperatives have been added periodically. Moreover, it is not certain that the Soviet authorities have consistently revised reported employment figures for earlier years when some branch components have been reclassified under other branches. The most important example of such a change in recent years was the transfer of the coke-chemical industry, refractory materials, and some other activities into ferrous metals.

APPENDIX C. DERIVATION OF INDEXES OF CAPITAL SERVICES

1. DESCRIPTION OF INDEXES

Although an estimate of the services of both fixed and working capital would be desirable in the calculation of factor productivity, the lack of data on working capital in constant prices precludes the construction of an accurate series for the various branches of industry. The fixed capital itself excludes "unproductive" capital as the Soviet authorities define it—that is, capital in communal housing, and social-cultural services—and capital in subsidiary agricultural activities of industrial enterprises. Increases in "unproductive" capital conceivably could raise output and productivity by improving the morale of the work force, but such increases would not affect inputs as used in this paper.

[40] Narkhoz 1958, p. 665; Narkhoz 1959, p. 596; Narkhoz 1960, p. 645; Narkhoz 1961, p. 602; Narkhoz 1962, p. 488; Narkhoz 1963, p. 506; Narkhoz 1964, p. 590.
[41] Vestnik statistiki, no. 5, 1961, p. 3–14.
[42] U.S.S.R., Central Statistical Administration. "SSSR v tsifrakh v 1961 godu," Moscow, 1962, p. 314. (Hereafter referred to as Tsifrakh, respective years.)

Like the labor input series, the data on fixed capital by branch are on an enterprise basis or are classified on the basis of the primary product of the enterprise.[43] Adopting the assumption that indexes of capital services can be approximated by indexes of average annual gross fixed capital stock, this paper relies heavily on official Soviet data. The index of first-of-year capital stock for all industry is the official Soviet capital stock index; the indexes for the nine branches of industry are provided by Soviet sources for 1953, 1955, and 1958–62. No index numbers are reported for 1950, 1954, or 1956–57, or 1963–64; and therefore, they must be estimated from other sources of information on capital stock. The index of annual capital services for all industry and for the branches are then constructed by averaging end-of-year indexes.

The officially reported branch indexes of capital stock have been supplemented in two main respects. For the missing years, officially reported branch distributions of capital stock were used to fill out the series. Although the index for industry is a constant cost index, the branch distributions of capital stock given for 1950, 1953, and 1954 are in terms of book value or original cost. The revaluation reduced the value of the productive capital stock in industry by 2 percent compared with the original cost valuation, but the value of individual branches changed in varying amounts depending on the branch structure of productive assets. Because investment costs were higher in 1949–55 than before 1949 or after 1955, those branches which acquired a large part of their capital stock between 1949 and 1954 would tend to have a higher value of capital in original cost prices than in 1955 replacement prices. On the other hand, because pre-1949 investment costs were appreciably lower than 1955 replacement prices, those branches with relatively old asset structures tended to have lower values of capital stock in original cost prices than in 1955 prices. Thus for those branches with relatively ancient asset structures the growth of capital inputs is understated in 1950–53, and the growth of factor productivity is overstated.

The second respect in which the officially reported branch indexes were supplemented concerns the fuel industries. Lacking official indexes for the coal and petroleum and natural gas branches, special estimates had to be constructed as described below.

2. DERIVATION OF INDEXES OF CAPITAL STOCK

The first of year and average annual indexes are presented in Table 8. Indexes of end-of-year values for industry as a whole for all years and for all branches (except coal and petroleum products and natural gas) for 1953, 1955, and 1958–62 are reported in various statistical abstracts.[44]

The first of year indexes of capital stock in these branches for the remaining years are estimated as follows:

(1) Jan. 1, 1950—It is assumed that the branch distribution of capital stock at the beginning of 1950 was the same as at the end of 1950. Therefore the percentage growth in each branch during 1950 is equal to the percentage growth in all industry.

(2) Jan. 1, 1954—The growth in each branch between Jan. 1, 1951, and Jan. 1, 1954 is estimated as equal to the percentage growth in all industrial fixed capital (in comparable prices) multiplied by the ratio of the branch share of industrial fixed capital on Jan. 1, 1954, to the branch share on Jan. 1, 1951. These shares are based on original cost valuations.[45]

(3) Jan. 1, 1952, and Jan. 1, 1953—For each branch the growth between Jan. 1, 1951, and Jan. 1, 1954 is interpolated based on the relative change in total industrial fixed capital.

(4) Jan. 1, 1955—The same procedure as that used for Jan. 1, 1954 is applied (See (2), above).

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[43] For example, the fixed assets of a woodworking shop subordinated to a machine building plant will be included in the fixed assets for "machine building—metalworking," not "wood, woodworking, and paper." In one sense, the fixed assets data are on a sectoral or branch basis "otraslevoy metod." That is, assets pertaining to subsidiary agricultural production of an industrial enterprise will be classified with agricultural rather than industrial assets, and assets of an industrial enterprise subordinate to construction organizations, collective farms, and the like will be included in the fixed assets of industry. This indicates that the fixed assets of an industrial nature belonging to industrial cooperatives in the years before the industrial cooperatives were transferred into industry were classified with industrial assets. V. A. Goloshchapov, "Spravochnik po bukhalterskomu uchetu," Moscow 1957, p. 74, U.S.S.R. Central Statistical Administration. *Promyshlennost' SSSR. Moscow*, 1957, p. 5; P. Bunich, "Pereotsenka osnovnykh fondov," Moscow, 1959. pp. 50–53.

[44] Promyshlennost' 1964, p. 68–69; Narkhoz 1961, p. 68; Narkhoz 1963, p. 55; Narkhoz 1964, p. 68; Tsifrakh 1965, p. 23, 27.

[45] Narkhoz 1958, p. 133.

TABLE 8.—*U.S.S.R.: Indexes of capital stock in industry, by branch, 1950–65*

[1950=100]

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Industry:																
As of Jan. 1	100.0	111.5	123.8	137.7	152.3	170.0	190.8	213.1	234.6	263.8	290.8	327.7	363.8	402.3	450.8	495.4
Average annual	100.0	111.3	123.6	137.1	152.4	170.6	191.0	211.7	235.6	262.2	292.4	327.0	362.2	403.4	447.4	491.0
Ferrous metals:																
As of Jan. 1	100.0	111.5	123.8	137.7	152.3	166.9	182.8	206.4	231.8	252.8	280.2	321.4	354.8	392.9	440.4	433.7
Average annual	100.0	111.3	123.6	137.1	150.9	165.3	184.0	207.2	229.1	252.0	284.4	319.7	353.5	394.0	436.9	
Coal:																
As of Jan. 1	100.0	111.5	123.8	135.2	156.6	173.9	190.8	211.1	235.2	261.8	(285.4)	304.2	320.4	337.0	355.6	377.8
Average annual	100.0	111.3	122.5	138.0	156.3	172.4	190.0	211.0	235.0	258.7	278.8	295.3	310.8	327.5	346.8	
Petroleum products and natural gas:																
As of Jan. 1	100.0	111.5	128.4	147.9	170.5	203.4	236.3	266.5	300.3	341.7	384.5	417.4	454.9	496.3	542.4	595.0
Average annual	100.0	113.4	130.6	150.5	176.8	207.9	237.7	268.0	303.5	343.4	379.1	412.4	449.7	491.1	537.8	
Machine building and metalworking:																
As of Jan. 1	100.0	111.5	120.6	130.5	141.3	151.5	162.5	176.6	190.6	203.5	221.8	241.6	268.5	301.0	330.8	363.0
Average annual	100.0	109.7	118.7	128.5	138.4	148.5	160.3	173.6	186.3	201.1	219.1	241.2	269.3	298.7	328.0	
Construction materials:																
As of Jan. 1	100.0	111.5	130.4	152.5	178.3	208.3	244.3	317.1	402.4	497.5	600.9	729.2	841.6	946.8	1,045.3	1,148.5
Average annual	100.0	114.4	133.8	156.4	182.8	214.0	265.4	340.2	425.5	519.3	628.9	742.7	845.6	941.9	1,037.3	
Light industry:																
As of Jan. 1	100.0	111.5	120.1	129.3	139.4	151.8	165.9	176.7	184.6	203.5	224.4	248.1	267.6	288.6	316.0	363.3
Average annual	100.0	109.5	117.9	127.0	137.7	150.2	162.0	170.8	183.5	202.3	223.4	243.8	263.0	285.9	321.2	
Food industry:																
As of Jan. 1	100.0	111.5	120.0	129.1	138.9	147.9	157.0	172.2	192.5	218.1	241.7	269.5	295.9	320.9	355.9	386.4
Average annual	100.0	109.5	117.8	126.7	135.6	144.2	155.7	172.4	194.1	217.4	241.7	267.3	291.6	320.0	351.0	
Chemicals:																
As of Jan. 1	100.0	111.5	122.2	133.9	146.7	164.9	184.8	214.0	237.1	267.0	312.5	365.3	418.1	501.7	631.6	680.8
Average annaul	100.0	110.5	121.1	132.7	147.3	165.3	188.6	213.3	238.3	274.0	320.5	370.4	434.9	535.8	620.5	
Forest products:																
As of Jan. 1	100.0	111.5	123.8	137.7	152.3	163.1	175.1	200.0	211.5	223.9	242.2	269.6	292.4	313.7	344.8	373.0
Average annual	100.0	111.3	123.6	137.1	149.1	159.9	177.4	194.6	205.9	220.4	242.0	265.7	286.6	311.3	339.4	

(5) Jan. 1, 1957 and Jan. 1, 1958—Index numbers for these years are interpolated on the basis of capital stock indexes for Jan. 1, 1956, Jan. 1, 1957, Jan. 1, 1958, and Jan. 1, 1959. These indexes in turn are derived from output-capital ratios and indexes of GVO.[46] Each of these indexes in turn was adjusted to make the total growth from Jan. 1, 1956 to Jan. 1, 1959 conform to the growth reported in *Promyshlennost' SSSR*.[47] Only for construction materials does the correction factor for annual growth amount to more than 2 percent.

(6) Jan. 1, 1964 and Jan. 1, 1965—The growth in fixed capital in each branch compared to Jan. 1, 1963 is estimated from the growth in all industrial fixed capital and the change in branch shares.[48]

The estimation of capital stock indexes for the coal and petroleum products and natural gas branches must be carried out separately because the Soviets publish only an index for all fuels. It is first assumed that the share of the coal branch in total industrial capital stock did not change during 1950 and 1951. Therefore the index of capital stock in the coal industry for Jan. 1, 1951 and Jan. 1, 1952 is the same as that for all industry. This assumption is fairly plausible; the share of the coal industry in total industrial capital (in comparable prices) did not change between Jan. 1, 1952 and Jan. 1, 1959.

The index of growth in capital stock from Jan. 1, 1952 to Jan. 1, 1959 has been reported in comparable prices for the Ministry of the Coal Industry.[49] As the (predominant) share in total production of the enterprises covered by this index did not change much over the period, it is used as if it were an index for the coal industry as a whole. The growth in capital stock during 1959 is estimated at 9 percent based on a comparison of the previous growth in capital stock and investment.

Between Jan. 1, 1960 and Jan. 1, 1965 capital stock in the coal industry increased by 32.4 percent. The total increase was 2.28 billion rubles and total investments less change in unfinished construction was 4.974 billion rubles.[50] Using the ratio of change in capital stock to investment (.458), values for capital stock were interpolated for the intervening years.

For petroleum products and natural gas it is assumed that the rate of growth in capital stock equaled that for all industry during 1950. From Jan. 1, 1951 to Jan. 1, 1954, growth in capital stock is estimated by multiplying the index of growth in total capital stock by the ratio of the branch shares of industrial

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[46] N. M. Osobina, ed, "Ocherki po sovremmenoy i zarubezhnoy ekonomike; Vypusk II," Moscow, 1961, p. 54, Vypusk III, Moscow, 1962, p. 110; K. A. Petrosyan, ed., "Ispolzovaniye osnovnykh proizvodstvennykh fondov v promyshlennosti SSSR," Moscow, 1962, pp. 34, 85, 119, 176, 187.

[47] Op. cit., p. 68–69.

[48] Ibid., p. 73; Narkhoz 1963, p. 127; Narkhoz 1964, p. 142–143.

[49] G. A. Burshtein, "Osnovnyye fondy ugol'noy promyshlennosti." Moscow, 1963, p. 97. Burshtein gives an index for capital stock in July 1, 1955 prices with 1951 as a base. The base is assumed to be (although not so stated) end of 1951 in accord with usual Soviet practice.

[50] Narkhoz 1964, pp. 68, 142, 516, 523; Narkhoz 1959, pp. 67–68; U.S.S.R., Central Statistical Administration, "Kapital'noye stroitel'stvo v. SSSR," Moscow, 1961, pp. 67, 126; Narkhoz 1962, p. 439; Narkhoz 1963, pp. 455, 461.

fixed capital (at original cost) on Jan. 1, 1954 and Jan. 1, 1951.[51] The indexes for intervening years are interpolated.

The growth in capital stock in the petroleum products and natural gas sector after Jan. 1, 1954 is estimated as follows. The Soviets have reported absolute values of capital stock for this branch as well as for all fuels on Jan. 1, 1960 and Jan. 1, 1965.[52] The absolute value of capital stock for all fuels can be computed for Jan. 1, 1954, Jan. 1, 1956, and for the beginning of the years 1959–65.[53] The value of capital stock in the coal industry has been estimated for Jan. 1, 1954 and Jan. 1, 1956. The values of capital stock in other fuels (excluding coal, oil, and gas) can be estimated at .49 and .72 billion rubles, based on the trend in the share of these other fuels in the capital stock of all fuels (at original cost). Therefore, the values of capital stock for petroleum products and natural gas for Jan. 1, 1954 and Jan. 1, 1956 can be estimated by subtraction.

Given benchmark values for capital stock in petroleum products and natural gas on Jan. 1, 1954, Jan. 1, 1956, Jan. 1, 1960, and Jan. 1, 1965:

(1) the value for Jan. 1, 1955 is estimated as an average of the values for Jan. 1, 1954, and Jan. 1, 1956.

(2) the values betweeen Jan. 1, 1956 and Jan. 1, 1960 and between Jan. 1, 1960 and Jan. 1, 1965 were interpolated based on the relation of investment less the change in unfinished construction to the change in capital stock, as was done for the coal industry. During 1956–59 the apparent ratio in the change in capital stock to the investment less the change in unfinished construction was .555; the comparable ratio during 1960–64 was .452.[54]

The primary reasons for low increment ratios in fuels are: (1) exploratory drilling costs in oil that yield dry wells are included in investment totals but do not appear as capital stock, (2) producing wells that result from exploratory drilling are entered as capital stock but at costs less than the actual drilling costs of the wells, and (3) the value of additions to capital stock is less than the value of investments because of retirements of fixed assets and increments in the stock of unfinished construction.

The average annual indexes of fixed capital stock for industry and for the nine branches of industry presented in Table 8 are calculated by averaging the beginning and end of year indexes. These average annual indexes are then used in the estimation of the growth in combined inputs of labor and capital and the trends in factor productivity.

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[51] Narkhoz 1958, p. 133.
[52] Narkhoz 1959, pp. 67–68; Narkhoz 1964, pp. 68, 142.
[53] Ibid.; Promyshlennost' 1964, p. 69.
[54] See footnote 50, above.

APPENDIX D

TABLE 9.—*U.S.S.R.: Estimated indexes of output, capital stock, labor services, weighted inputs, factor productivity, labor productivity and capital productivity in industry, by branch, selected years, 1950–65*

[1950=100]

INDUSTRY (20-PERCENT DISCOUNT OF GROWTH IN MBMW GVO)

	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Index of output	137.5	170.3	186.4	203.5	223.4	246.2	265.3	286.2	309.6	331.1	353.6	379.2
Index of capital stock (average annual)	137.1	170.6	191.0	211.7	235.6	262.2	292.4	327.0	362.0	403.4	447.4	491.0
Index of labor services:												
Man-hours	116.3	125.1	125.4	125.8	127.8	128.7	128.1	127.4	131.2	135.5	140.9	(147.0)
Adjusted employment	117.1	126.5	130.6	133.7	139.2	144.0	151.1	159.1	164.2	168.9	174.4	181.9
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	120.2	133.1	136.4	139.6	144.4	148.4	151.1	153.8	160.7	168.5	177.5	187.1
8 percent interest rate, 1960 weights	121.8	136.5	141.1	145.5	151.7	157.1	161.4	165.9	174.3	183.9	194.7	206.0
13 percent interest rate, 1960 weights	123.4	139.9	145.9	151.7	159.3	166.3	172.4	178.9	189.1	200.7	213.6	226.9
Employment: 8 percent interest rate, 1960 weights	122.4	137.5	145.3	152.1	161.3	170.3	181.8	194.7	204.9	215.5	227.0	240.2
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	114.4	127.9	136.7	145.8	154.7	165.9	175.6	186.1	192.7	196.5	199.2	202.7
8 percent interest rate, 1960 weights	112.9	124.8	132.1	139.9	147.3	156.7	164.4	172.5	177.6	180.0	181.6	184.1
13 percent interest rate, 1960 weights	111.4	121.7	127.8	134.1	140.2	148.0	153.9	160.0	163.7	165.0	165.5	167.1
Employment: 8 percent interest rate, 1960 weights	112.3	123.9	128.3	133.8	138.5	144.6	145.9	147.0	151.1	153.6	155.8	157.9
Indexes of labor productivity:												
Man-hours	118.2	136.1	148.6	161.8	174.8	191.3	207.1	224.6	236.0	244.4	251.0	258.0
Employment	117.4	134.6	142.7	152.2	160.5	171.0	175.6	180.0	188.6	196.0	202.8	208.5
Index of capital productivity	100.3	99.8	97.6	96.1	94.8	93.9	90.7	87.5	85.5	82.1	79.0	77.2

INDUSTRY (10-PERCENT DISCOUNT OF GROWTH IN MBMW GVO)

Index of output	138.7	172.9	189.9	208.0	229.1	253.5	274.1	297.0	322.7	346.7	371.5	399.5
Index of capital stock (average annual)	137.1	170.6	191.0	211.7	235.6	262.2	292.4	327.0	362.0	403.4	447.4	491.0
Index of labor services:												
Man-hours	116.3	125.1	125.4	125.8	127.8	128.7	128.1	127.4	131.2	135.5	140.9	(147.0)
Adjusted employment	117.1	126.5	130.6	133.7	139.2	144.0	151.1	159.1	164.2	168.9	174.4	181.9

Indexes of weight inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	120.2	133.1	136.4	139.6	144.4	148.4	151.1	153.8	160.7	168.5	177.5	187.1
8 percent interest rate, 1960 weights	121.8	136.5	141.1	145.5	151.7	157.1	161.4	165.9	174.3	183.9	194.7	206.0
13 percent interest rate, 1960 weights	123.4	139.9	145.9	151.7	159.3	166.3	172.4	178.9	189.1	200.7	213.6	226.9
Employment: 8 percent interest rate, 1960 weights	122.4	137.5	145.3	152.1	161.3	170.3	181.8	194.7	204.9	215.5	227.0	240.2
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	115.4	129.9	139.2	149.0	158.7	170.8	181.4	193.1	200.8	205.8	209.3	213.5
8 percent interest rate, 1960 weights	113.9	126.7	134.6	143.0	151.0	161.4	169.8	179.0	185.1	188.5	190.8	193.9
13 percent interest rate, 1960 weights	112.4	123.6	130.2	137.1	143.8	152.4	159.0	166.0	170.6	172.7	173.9	176.1
Employment: 8 percent interest rate, 1960 weights	113.3	125.7	130.7	136.8	142.0	148.9	150.8	152.5	157.5	160.9	163.7	166.3
Indexes of labor productivity:												
Man-hours	119.3	138.2	151.4	165.3	179.3	197.0	214.0	233.1	246.0	255.9	263.7	271.8
Employment	118.4	136.7	145.4	155.6	164.6	176.0	181.4	186.7	196.5	205.3	213.0	219.6
Index of capital productivity	101.2	101.3	99.4	98.3	97.2	96.7	93.7	90.8	89.1	85.9	83.0	81.4

INDUSTRY (30-PERCENT DISCOUNT OF GROWTH IN MBMW GVO)

Index of output	136.1	167.2	182.4	198.5	217.1	238.3	255.8	274.8	295.9	315.2	335.6	358.8
Index of capital stock (average annual)	137.1	170.6	191.0	211.7	235.6	262.2	292.4	327.0	362.0	403.4	447.4	491.0
Index of labor services:												
Man-hours	116.3	125.1	125.4	125.8	127.8	128.7	128.1	127.4	131.2	135.5	140.9	(147.0)
Adjusted employment	117.1	126.5	130.6	133.7	139.2	144.0	151.1	159.1	164.2	168.9	174.4	181.9
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	120.2	133.1	136.4	139.6	144.4	148.4	151.1	153.8	160.7	168.5	177.5	187.1
8 percent interest rate, 1960 weights	121.8	136.5	141.1	145.5	151.7	157.1	161.4	165.9	174.3	183.9	194.7	206.0
13 percent interest rate, 1960 weights	123.4	139.9	145.9	151.7	159.3	166.3	172.4	178.9	189.1	200.7	213.6	226.9
Employment: 8 percent interest rate, 1960 weights	122.4	137.5	145.3	152.1	161.3	170.3	181.8	194.7	204.9	215.5	227.0	240.2
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	113.2	125.6	133.7	142.2	150.3	160.6	169.3	178.7	184.1	187.1	189.1	191.8
8 percent interest rate, 1960 weights	111.7	122.5	129.3	136.4	143.1	151.7	158.5	165.6	169.8	171.4	172.4	174.2
13 percent interest rate, 1960 weights	110.3	119.5	125.0	130.8	136.3	143.3	148.4	153.6	156.5	157.0	157.1	158.1
Employment: 8 percent rate, 1960 weights	111.2	121.6	125.5	130.5	134.6	139.9	140.7	141.1	144.4	146.3	147.8	149.4
Indexes of labor productivity:												
Man-hours	117.0	133.7	145.5	157.8	169.9	185.2	199.7	215.7	225.5	232.6	238.2	244.1
Employment	116.2	132.2	139.7	148.5	156.0	165.5	169.3	172.7	180.2	186.6	192.4	197.3
Index of capital productivity	99.3	98.0	95.5	93.8	92.1	90.9	87.5	84.0	81.7	78.1	75.0	73.1

(Table 9 continues on p. 318.)

TABLE 9.—*U.S.S.R.: Estimated indexes of output, capital stock, labor services, weighted inputs, factor productivity, labor productivity, and capital productivity in industry, by branch—Selected years, 1950–65*—Continued

[1950=100]

FERROUS METALS

	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Index of output	143.1	175.0	189.7	201.1	216.0	236.8	257.5	278.4	300.8	319.5	345.2	.....
Index of capital stock (average annual)	137.1	165.3	184.0	207.2	229.1	252.0	284.4	319.7	353.5	394.0	436.9	.....
Index of labor services:												
Man-hours	116.1	121.4	119.3	115.9	114.8	113.9	119.4	122.4	125.3	130.0	135.0	.....
Adjusted employment	116.9	122.8	124.3	126.5	134.4	139.2	146.7	152.8	156.8	162.1	167.1	.....
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	121.4	132.0	134.1	135.6	138.3	141.1	150.9	158.6	165.8	175.4	185.4	.....
8 percent interest rate, 1960 weights	123.7	136.5	140.7	144.5	149.3	154.0	166.0	176.3	185.8	198.1	210.9	.....
13 percent interest rate, 1960 weights	125.3	139.9	145.6	151.4	157.8	164.1	178.0	190.4	201.9	216.5	231.7	.....
Employment: 8 percent interest rate, 1960 weights	124.2	137.5	144.3	152.6	164.6	174.4	188.7	202.3	213.6	227.2	240.8	.....
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	117.9	132.6	141.5	148.3	156.2	167.8	170.6	175.5	181.4	182.2	186.2	.....
8 percent interest rate, 1960 weights	115.7	128.2	134.8	139.2	144.7	153.8	155.1	157.9	161.9	161.3	163.7	.....
13 percent interest rate, 1960 weights	114.2	125.1	130.3	132.8	136.9	144.3	144.7	146.2	149.0	147.6	149.0	.....
Employment: 8 percent interest rate, 1960 weights	115.2	127.3	131.5	131.8	131.2	135.8	136.5	137.6	140.8	140.6	143.4	.....
Indexes of labor productivity:												
Man-hours	123.3	144.2	159.0	173.5	188.2	207.9	215.7	227.5	240.1	245.8	255.7	.....
Employment	122.4	142.5	152.6	159.0	160.7	170.1	175.5	182.2	191.8	197.1	206.6	.....
Index of capital productivity	104.4	105.9	103.1	97.1	94.3	94.0	90.5	87.1	85.1	81.1	79.0	.....

COAL

Index of output	122.0	149.7	164.1	177.0	189.8	195.2	199.6	199.7	203.6	209.6	218.0	.....
Index of capital stock (average annual)	138.0	172.4	190.0	211.0	235.0	258.7	278.8	295.3	310.8	327.5	346.8	.....
Index of labor services:												
Man-hours	107.5	121.2	126.9	127.6	125.2	117.4	106.3	99.7	98.4	97.8	98.8	.....
Ajusted employment	108.3	122.5	132.2	139.5	146.3	146.7	140.8	137.3	136.1	134.7	135.0	.....

Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	113.3	130.5	138.1	141.8	142.9	138.6	130.2	125.2	125.3	126.1	128.6	
8 percent interest rate, 1960 weights	115.6	134.2	142.7	147.6	150.3	147.6	140.6	136.6	137.4	138.9	142.2	
13 percent interest rate, 1960 weights	117.3	137.1	146.2	152.2	156.1	154.8	149.0	145.8	147.2	149.3	153.3	
Employment: 8 percent interest rate, 1960 weights	116.2	135.3	146.9	157.3	167.9	172.9	171.6	171.4	172.9	174.3	177.5	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	107.7	114.7	118.8	124.8	132.8	140.8	153.3	159.5	162.5	166.2	169.5	
8 percent interest rate, 1960 weights	105.5	111.5	115.0	119.9	126.3	132.2	142.0	146.2	148.2	150.9	153.3	
13 percent interest rate, 1960 weights	104.0	109.2	112.2	116.3	121.6	126.1	134.0	137.0	138.3	140.4	142.2	
Employment: 8 percent interest rate, 1960 weights	105.0	110.6	111.7	112.5	113.0	112.9	116.3	116.5	117.8	120.3	122.8	
Indexes of labor productivity:												
Man-hours	113.5	123.5	129.3	138.7	151.6	166.3	187.8	200.3	206.9	214.3	220.6	
Employment	112.7	122.2	124.1	126.9	129.7	133.1	141.8	145.4	149.6	155.6	161.5	
Index of capital productivity	88.4	86.8	86.4	83.9	80.8	75.5	71.6	67.6	65.5	64.0	62.9	

PETROLEUM PRODUCTS AND NATURAL GAS

Index of output	139.6	174.8	208.5	244.9	282.1	323.1	368.0	413.2	469.0	521.1	570.7	
Index of capital stock (average annual)	150.5	207.9	237.7	268.0	303.5	343.4	379.1	412.4	449.7	491.1	537.8	
Index of labor services:												
Man-hours	117.7	133.3	132.5	133.4	142.5	140.8	136.3	137.2	134.1	134.8	137.5	
Adjusted employment	118.5	134.8	138.0	141.3	152.2	155.4	160.9	170.7	167.4	167.4	169.6	
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	137.1	175.6	190.4	205.6	227.7	244.7	257.0	271.4	283.9	300.5	320.3	
8 percent interest rate, 1960 weights	142.2	187.7	207.8	228.3	255.1	279.7	299.6	320.2	340.5	364.8	393.0	
13 percent interest rate, 1960 weights	144.0	191.9	214.0	236.4	264.9	292.5	315.3	338.3	361.7	389.1	420.7	
Employment: 8 percent interest rate, 1960 weights	142.4	188.2	209.8	231.3	258.9	286.2	311.3	336.7	358.3	383.4	412.4	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	101.8	99.5	109.5	119.1	123.9	132.0	143.2	152.2	165.2	173.4	178.2	
8 percent interest rate, 1960 weights	98.2	93.1	100.3	107.3	110.6	115.5	122.8	129.0	137.7	142.8	145.2	
13 percent interest rate, 1960 weights	96.9	91.1	97.4	103.6	106.5	110.5	116.7	122.1	129.7	133.9	135.7	
Employment: 8 percent interest rate, 1960 weights	98.0	92.9	99.4	105.9	109.0	112.9	118.2	122.7	130.9	135.9	138.4	
Indexes of labor productivity:												
Man-hours	118.6	131.1	157.4	183.6	198.0	229.5	270.0	301.2	349.7	386.6	415.1	
Employment	117.8	129.7	151.1	173.3	185.3	207.9	228.7	242.1	280.2	311.3	336.5	
Index of capital productivity	92.8	84.1	87.7	91.4	92.9	94.1	97.1	100.2	104.3	106.1	106.1	

(Table 9 continues on page 320.)

TABLE 9.—*U.S.S.R.: Estimated indexes of output, capital stock, labor services, weighted inputs, factor productivity, labor productivity and capital productivity in industry, by branch—Selected years, 1950–65*—Continued

[1950=100]

MACHINE BUILDING AND METALWORKING (10-PERCENT DISCOUNT OF GROWTH IN GVO)

	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Index of output	152.3	204.5	230.5	257.7	289.5	329.1	372.9	423.2	481.5	538.3	583.8	.....
Index of capital stock (average annual)	128.5	148.5	160.3	173.6	186.3	201.1	219.1	241.2	269.3	298.7	328.0	.....
Index of labor services:												
Man-hours	118.7	130.7	133.8	136.9	140.4	142.0	144.7	151.0	159.6	169.0	177.8	.....
Adjusted employment	119.5	132.2	139.4	145.0	151.3	158.1	170.6	187.3	198.7	209.4	218.7	.....
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	120.4	133.7	138.2	142.9	147.7	151.2	155.9	164.3	175.4	187.2	198.5	.....
8 percent interest rate, 1960 weights	120.5	133.9	138.5	143.2	148.2	151.7	156.6	165.1	176.3	188.3	199.7	.....
13 percent interest rate, 1960 weights	121.1	134.9	140.0	145.3	150.7	154.9	160.5	169.8	181 9	194.9	207.2	.....
Employment: 8 percent interest rate, 1960 weights	121.2	135.2	143.1	150.0	157.4	165.5	178.9	196.5	210.5	224.0	236.2	.....
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	126.5	153.0	166.8	180.3	196.0	217.7	239.2	257.6	274.5	287.6	294.1	.....
8 percent interest rate, 1960 weights	126.4	152.7	166.4	180.0	195.3	216.9	238.1	256.3	273.1	285.9	292.3	.....
13 percent interest rate, 1960 weights	125.8	151.6	164.6	177.4	192.1	212.5	232.3	249.2	264.7	276.2	281.8	.....
Employment: 8 percent interest rate, 1960 weights	125.7	151.3	161.1	171.8	183.9	198.9	208.4	215.4	228.7	240.3	247.2	.....
Indexes of labor productivity:												
Man-hours	128.3	156.5	172.3	188.2	206.2	231.8	257.7	280.3	301.7	318.5	328.3	.....
Employment	127.4	154.7	165.4	177.7	191.3	208.2	218.6	225.9	242.3	257.1	266.9	.....
Index of capital productivity	118.5	137.7	143.8	148.4	155.4	163.6	170.2	175.5	178.8	180.2	178.0	.....

MACHINE BUILDING AND METALWORKING (20-PERCENT DISCOUNT OF GROWTH IN GVO)

Index of output	145.7	189.7	211.1	233.2	258.8	290.3	324.7	363.7	408.2	451.0	484.9	.....
Index of capital stock (average annual)	128.5	148.5	160.3	173.6	186.3	201.1	219.1	241.2	269.3	298.7	328.0	.....
Index of labor services:												
Man-hours	118.7	130.7	133.8	136.9	140.4	142.0	144.7	151.0	159.6	169.0	177.8	.....
Adjusted employment	119.5	132.2	139.4	145.0	151.3	158.1	170.6	187.3	198.7	209.4	218.7	.....

Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	120.4	133.7	138.2	142.9	147.7	151.2	155.9	164.3	175.4	187.2	198.5	
8 percent interest rate, 1960 weights	120.5	133.9	138.5	143.2	148.1	151.7	156.6	165.1	176.3	188.3	199.7	
13 percent interest rate, 1960 weights	121.1	134.9	140.0	145.3	150.7	154.9	160.5	169.8	181.9	194.9	207.2	
Employment: 8 percent interest rate, 1960 weights	121.2	135.2	143.1	150.0	157.4	165.5	178.9	196.5	210.5	224.0	236.2	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	121.0	141.9	152.7	163.2	175.2	192.0	208.3	221.4	232.7	240.9	244.3	
8 percent interest rate, 1960 weights	120.9	141.7	152.4	162.8	174.7	191.4	207.3	220.3	231.5	239.5	242.8	
13 percent interest rate, 1960 weights	120.3	140.6	150.8	160.5	171.7	187.4	202.3	214.2	224.4	231.4	234.0	
Employment: 8 percent interest rate, 1960 weights	120.2	140.3	147.5	155.5	164.4	175.4	181.5	185.1	193.9	201.3	205.3	
Indexes of labor productivity:												
Man-hours	122.7	145.1	157.8	170.3	184.3	204.4	224.4	240.9	255.8	266.9	272.7	
Employment	121.9	143.5	151.4	160.8	171.0	183.6	190.3	194.2	205.4	215.4	221.7	
Index of capital productivity	113.4	127.7	131.7	134.3	138.9	144.4	148.2	150.8	151.6	151.0	147.8	

MACHINE BUILDING AND METALWORKING (30-PERCENT DISCOUNT OF GROWTH IN GVO)

Index of output	139.4	176.0	193.4	211.1	231.3	255.9	282.4	312.1	345.5	377.2	402.0	
Index of capital stock (average annual)	128.5	148.5	160.3	173.6	186.3	201.1	219.1	241.2	269.3	298.7	328.0	
Index of labor services:												
Man-hours	118.7	130.7	133.8	136.9	140.4	142.0	144.7	151.0	159.6	169.0	177.8	
Adjusted employment	119.5	132.2	139.4	145.0	151.3	158.1	170.6	187.3	198.7	209.4	218.7	
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	120.4	133.7	138.2	142.9	147.7	151.2	155.9	164.3	175.4	187.2	198.5	
8 percent interest rate, 1960 weights	120.5	133.9	138.5	143.2	148.1	151.7	156.6	165.1	176.3	188.3	199.7	
13 percent interest rate, 1960 weights	121.1	134.9	140.0	145.3	150.7	154.9	160.5	169.8	181.9	194.9	207.2	
Employment: 8 percent interest rate, 1960 weights	121.2	135.2	143.1	150.0	157.4	165.5	178.9	196.5	210.5	224.0	236.2	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	115.8	131.6	139.9	147.7	156.6	169.2	181.1	190.0	197.0	201.5	202.5	
8 percent interest rate, 1960 weights	115.7	131.4	139.6	147.4	156.2	168.7	180.3	189.0	196.0	200.3	201.3	
13 percent interest rate, 1960 weights	115.1	130.5	138.1	145.3	153.5	165.2	176.0	183.8	189.9	193.5	194.0	
Employment: 8 percent interest rate, 1960 weights	115.0	130.2	135.2	140.7	147.0	154.6	157.9	158.8	164.1	168.4	170.2	
Indexes of labor productivity:												
Man-hours	117.4	134.7	144.5	154.2	164.7	180.2	195.2	206.7	216.5	223.2	226.1	
Employment	116.7	133.1	138.7	145.6	152.9	161.9	165.5	166.6	173.9	180.1	183.8	
Index of capital productivity	108.5	118.5	120.6	121.6	124.2	127.3	128.9	129.4	128.3	126.3	122.6	

(Table 9 continues on page 322.)

TABLE 9.—*U.S.S.R.: Estimated indexes of output, capital stock, labor services, weighted inputs, factor productivity, labor productivity and capital productivity in industry, by branch—Selected years, 1950–65*—Continued

[1950=100]

CONSTRUCTION MATERIALS

	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Index of output	154.8	215.0	245.8	296.0	355.2	423.9	489.0	540.5	588.6	622.1	663.4	
Index of capital stock (average annual)	156.4	214.0	265.4	340.2	425.5	519.3	628.9	742.7	845.6	941.9	1,037.3	
Index of labor services:												
Man-hours	130.3	149.1	144.8	160.9	178.3	186.9	195.9	195.5	195.9	194.2	195.7	
Adjusted employment	131.2	150.8	150.8	170.4	192.1	208.1	231.0	242.5	243.9	240.6	240.7	
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	133.7	156.8	157.6	178.7	201.4	215.6	230.6	235.7	240.4	242.2	247.2	
8 percent interest rate, 1960 weights	136.6	163.8	169.5	195.5	223.5	243.8	265.3	276.6	286.5	292.8	301.9	
13 percent interest rate, 1960 weights	138.4	168.0	176.9	206.0	237.6	261.9	287.9	303.7	317.4	327.0	339.3	
Employment: 8 percent interest rate, 1960 weights	137.3	165.2	174.7	204.0	236.2	264.0	299.7	324.4	337.0	343.1	351.9	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	115.8	137.1	156.0	165.6	176.4	196.6	212.1	229.3	244.8	256.9	268.4	
8 percent interest rate, 1960 weights	113.3	131.3	145.0	151.4	158.9	173.9	184.3	195.4	206.2	212.5	219.7	
13 percent interest rate, 1960 weights	111.8	128.0	138.9	143.7	149.5	161.9	169.9	178.0	185.4	190.2	195.5	
Employment: 8 percent interest rate, 1960 weights	112.7	130.1	140.7	145.1	150.4	160.6	163.2	166.6	174.7	181.3	188.5	
Indexes of labor productivity:												
Man-hours	118.8	144.2	169.8	184.0	199.2	226.8	249.6	276.5	300.5	320.3	339.0	
Employment	118.0	142.6	163.0	173.7	184.9	203.7	211.7	222.9	241.3	258.6	275.6	
Index of capital productivity	99.0	100.5	92.6	87.0	83.5	81.6	77.8	72.8	69.6	66.0	64.0	

LIGHT INDUSTRY

Index of output	137.1	262.1	172.9	184.4	199.4	212.9	225.3	232.5	242.1	247.5	257.8	
Index of capital stock (average annual)	127.0	150.2	162.0	170.8	183.5	202.3	223.4	243.8	263.0	285.9	321.2	
Index of labor services:												
Man-hours	118.5	127.2	121.9	119.6	124.3	128.0	129.5	123.3	125.4	128.2	130.6	
Adjusted employment	119.3	128.6	127.0	126.7	132.8	137.6	148.7	153.2	156.3	156.6	160.9	

Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	119.3	129.3	125.4	123.9	129.2	134.0	136.8	132.0	135.0	137.0	142.9	
8 percent interest rate, 1960 weights	119.4	129.5	125.8	124.4	129.7	134.6	137.5	132.9	136.0	138.1	144.2	
13 percent interest rate, 1960 weights	119.8	130.6	127.6	126.6	132.3	137.7	141.3	137.5	141.2	143.8	150.8	
Employment: 8 percent interest rate, 1960 weights	120.1	130.8	130.4	130.9	137.6	143.6	155.5	161.2	165.5	167.3	173.6	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	114.9	125.4	137.9	148.8	154.3	158.9	164.7	176.1	179.3	180.7	180.4	
8 percent interest rate, 1960 weights	114.8	125.2	137.4	148.2	153.7	158.2	163.9	174.9	178.0	179.2	178.8	
13 percent interest rate, 1960 weights	114.4	124.1	135.5	145.7	150.7	154.6	159.4	169.1	171.5	172.1	171.0	
Employment: 8 percent interest rate, 1960 weights	114.2	123.9	132.6	140.9	144.9	148.3	144.9	144.2	146.3	147.9	148.5	
Indexes of labor productivity:												
Man-hours	115.7	127.4	141.8	154.2	160.4	166.3	174.0	188.6	193.1	196.1	197.4	
Employment	114.9	126.0	136.1	145.5	150.2	154.7	151.5	151.8	154.9	158.0	160.2	
Index of capital productivity	108.0	107.9	106.7	108.0	108.7	105.2	100.9	95.4	92.1	86.6	80.3	
FOOD INDUSTRY												
Index of output	138.6	157.5	173.3	185.5	197.2	214.4	218.3	236.0	249.0	249.4	261.5	
Index of capital stock (average annual)	126.7	144.2	155.7	172.4	194.1	217.4	241.7	267.3	291.6	320.0	351.0	
Index of labor services:												
Man-hours	113.4	119.3	120.2	122.1	123.2	124.9	115.2	111.4	112.0	117.2	121.5	
Adjusted employment	114.2	120.6	125.2	129.2	131.5	134.0	132.0	138.4	139.7	145.4	149.6	
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	116.7	125.3	128.6	133.6	138.7	144.3	139.7	139.9	143.6	152.2	160.1	
8 percent interest rate, 1960 weights	117.5	126.8	130.6	136.4	142.5	149.1	146.0	147.4	152.1	161.6	170.6	
13 percent interest rate, 1960 weights	118.7	128.9	133.7	140.7	148.4	156.8	156.1	159.5	165.8	176.9	187.7	
Employment: 8 percent interest rate, 1960 weights	118.1	127.7	134.2	141.7	148.9	156.4	160.2	170.9	176.8	187.2	196.5	
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	118.8	125.7	134.8	138.8	142.2	148.6	156.3	168.7	173.4	163.9	163.3	
8 percent interest rate, 1960 weights	118.0	124.2	132.7	136.0	138.4	143.8	149.5	160.1	163.7	154.3	153.3	
13 percent interest rate, 1960 weights	116.8	122.2	129.6	131.8	132.9	136.7	139.8	148.0	150.2	141.0	139.3	
Employment: 8 percent interest rate, 1960 weights	117.4	123.3	129.1	130.9	132.4	137.1	136.3	138.1	140.8	133.2	133.1	
Indexes of labor productivity:												
Man-hours	122.2	132.0	144.2	151.9	160.1	171.7	189.5	211.8	222.3	212.8	215.2	
Employment	121.4	130.6	138.4	143.6	150.0	160.0	165.4	170.5	178.2	171.5	174.8	
Index of capital productivity	109.4	109.2	111.3	107.6	101.6	98.6	90.3	88.3	85.4	77.9	74.5	

(Table 9 continues on page 324.)

TABLE 9.—*U.S.S.R.: Estimated indexes of output, capital stock, labor services, weighted inputs, factor productivity, labor productivity and capital productivity in industry, by branch—Selected years, 1950–65*—Continued

[1950=100]

CHEMICALS

	1953	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Index of output	145.9	187.5	205.9	230.4	259.3	289.7	316.3	341.2	371.9	409.3	459.9	--------
Index of capital stock (average annual)	132.7	165.3	188.6	213.3	238.3	274.0	320.5	370.4	434.9	535.8	620.5	--------
Index of labor services:												
Man-hours	123.2	136.3	131.9	130.5	127.8	125.7	130.6	137.4	155.5	177.3	194.3	--------
Adjusted employment	124.1	137.8	137.5	138.4	144.4	152.6	160.0	170.1	193.2	219.2	238.4	--------
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	125.5	143.0	144.2	147.6	149.3	152.7	163.5	176.1	201.1	233.8	259.7	--------
8 percent interest rate, 1960 weights	126.4	145.8	149.5	155.0	158.9	165.1	178.8	194.4	222.9	261.1	291.7	--------
13 percent interest rate, 1960 weights	127.2	148.1	153.8	161.2	167.1	175.7	192.1	210.5	242.0	285.3	320.1	--------
Employment: 8 percent interest rate, 1960 weights	127.0	146.9	153.6	161.0	172.1	187.3	204.0	223.4	256.7	299.7	333.2	--------
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	116.3	131.1	142.8	156.1	173.7	189.7	193.5	193.8	184.9	175.1	177.1	--------
8 percent interest rate, 1960 weights	115.4	128.6	137.7	148.6	163.2	175.5	176.9	175.5	166.8	156.8	157.7	--------
13 percent interest rate, 1960 weights	114.7	126.6	133.9	142.9	155.2	164.9	164.7	162.1	153.7	143.5	143.7	--------
Employment: 8 percent interest rate, 1960 weights	114.9	127.6	134.0	143.1	150.7	154.7	155.0	152.7	144.9	136.6	138.0	--------
Indexes of labor productivity:												
Man-hours	118.4	137.6	156.1	176.6	202.9	230.5	242.2	248.3	239.2	230.9	236.7	--------
Employment	117.6	136.1	149.7	166.5	179.6	189.8	197.7	200.6	192.5	186.7	192.9	--------
Index of capital productivity	109.9	113.4	109.2	108.0	108.8	105.7	98.7	92.1	85.5	76.4	74.1	--------

Index of output	121.8	144.6	150.3	162.2	177.3	196.0	198.6	201.9	210.4	222.2	233.2	--------
Index of capital stock (average annual)	137.1	159.9	177.4	194.6	205.9	220.4	242.0	265.7	286.6	311.3	339.4	--------
Index of labor services:												
Man-hours	--------	106.2	101.8	98.2	93.8	92.0	83.1	76.7	76.5	77.9	78.5	--------
Adjusted employment	--------	107.4	104.4	101.7	99.7	99.3	93.5	93.3	93.3	94.6	94.7	--------
Indexes of weighted inputs, geometric function:												
Man-hours:												
8 percent interest rate, 1950 weights	--------	111.5	108.8	106.6	103.1	102.2	94.5	89.0	89.6	92.0	93.6	--------
8 percent interest rate, 1960 weights	--------	115.3	113.8	112.6	109.8	109.6	102.9	98.3	99.6	102.8	105.2	--------
13 percent interest rate, 1960 weights	--------	117.6	117.0	116.5	114.2	114.5	108.6	104.6	106.4	110.1	113.2	--------
Employment: 8 percent interest rate, 1960 weights	--------	116.3	116.1	115.8	115.3	116.5	113.1	115.0	116.8	120.0	122.2	--------
Indexes of factor productivity:												
Man-hours:												
8 percent interest rate, 1950 weights	--------	129.7	138.1	152.2	172.0	191.8	210.2	226.9	234.8	241.5	249.1	--------
8 percent interest rate, 1960 weights	--------	125.4	132.1	144.0	161.5	178.8	193.0	205.4	211.2	216.1	221.7	--------
13 percent interest rate, 1960 weights	--------	123.0	128.5	139.2	155.3	171.2	182.9	193.0	197.7	201.8	206.0	
Employment: 8 percent interest rate, 1960 weights	--------	124.3	129.5	140.1	153.8	168.2	175.6	175.6	180.1	185.2	190.8	--------
Indexes of labor productivity:												
Man-hours	--------	136.2	147.6	165.2	189.0	213.0	239.0	263.2	275.0	285.2	297.1	--------
Employment	--------	134.6	144.0	159.5	177.8	197.4	212.4	216.4	225.5	234.9	246.3	--------
Index of capital productivity	--------	90.4	84.7	83.4	86.1	88.9	82.1	76.0	73.4	71.4	68.7	--------

COMPUTERS IN THE SOVIET ECONOMY

BY

KATHERINE MILLER

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COMPUTERS IN THE SOVIET ECONOMY

I. Introduction

The Soviet Union has not kept pace with the United States in development of electronic computer technology. Obviously, this lag has not prevented the U.S.S.R. from achieving spectacular results in its military/space programs. In the area of economic, business, and industrial accounting, however, the lack of electronic data processing equipment and the rudimentary state of development of this branch of the computer industry are causing the Soviet leadership considerable concern. The directives for the new 5-year plan (1966–70) give a major emphasis to increasing the production of computers, particularly those capable of handling large amounts of data.

The attention now accorded electronic computers by the business communities and governments of the technologically advanced nations may be attributed primarily to the promotional work of the free world computer producers (principally U.S. firms), which undertook to study economic activity with the specific aim of developing computers and computer techniques to lighten the burden of administration. To date, a similar promotional force has not existed in the centrally planned economies of the Communist countries, a fact that helps explain why the Soviet hierarchy is only now vigorously pressing for a program to equip its industrial enterprises and bureaucratic structure with computers for data processing and analysis.

Computer development work in the U.S.S.R. was concentrated initially at research institutes under the Academy of Sciences and was focused primarily on computers suitable for use in scientific research. Much discussion, as well as a moderate amount of real effort, has been given to the development of computer systems for process control, and heavy emphasis was placed on the development of analog and digital computers appropriate for priority military and space programs. Consequently, until recently, the Soviet computer industry did not have the priority task to design or to produce computers especially adapted to commercial or economic use, and little research was directed toward the development of the peripheral equipment or programing devices necessary for data processing. The U.S.S.R. lags about 5 years behind the United States in the use of computers for data processing. This lag resulted both from a tardy recognition of the value of computers for this purpose, and from the consequent parsimony in the allocation of resources to their development. There is little evidence that digital computers were routinely employed in data handling in the U.S.S.R. before 1960. Rather, they apparently were used almost exclusively for solving scientific and military problems. Following a belated awakening to the benefits that industrialized Western countries were realizing from the application of data handling computers in commercial activities, the U.S.S.R. about 1962, began installing

them at a slow but increasing rate in enterprises and state administrative organs for processing plan data, scheduling production, and performing accounting tasks.

In contrast to the U.S.S.R., free world countries, particularly the United States, employ computers in almost every phase of economic activity from market research to business accounting. U.S. computer manufacturers, stimulated by the sales potential of the business market, have concentrated since about 1955 on the development of expanded internal and external memory systems, on raising operating speeds, on increases in assortment and efficiency of input/output apparatus, and on making the computers easier to use. Ease of use has been facilitated by provision of additional programing languages and accessibility to the computer from remote consoles.

II. Requirements for Computers in the U.S.S.R.

Two factors have led to the recognition by Soviet officials in recent years of a greatly increased requirement for computers for the Soviet economy. One factor has been the increasing difficulty of contending with the flood of information that accompanies economic growth. The other is the growing conviction of Soviet planners that mathematical methods can be highly useful in economic planning.

It is obvious that the successful operation of a centrally controlled, highly industrialized economy depends on the ability to analyze vast amounts of data. In the Soviet Union, the collection, processing, transmission, storage, and arrayment of data on every aspect of economic life, transmitted between production, distribution and sales units and production control, statistical, and planning centers at various levels of authority, through multitudinous channels, presents a data processing task unparalleled in human experience. At present this task is performed at a high cost, mainly by vast numbers of clerks armed with abaci and desk calculators. Even punch card machinery, which has been in production for years in the U.S.S.R., contributes relatively little compared with the army of clerks. According to a Soviet source, some 10 million persons were employed in 1962 in all of the organs of state administrative-management, and some 3 million of these were engaged in accounting and record keeping alone.[1] Moreover, the volume of data-reporting on economic activity tends to increase faster than the growth of that activity. The preservation of the centralized system of economic management in the U.S.S.R. clearly depends, among other things, on achieving a very considerable increase in labor productivity in the processing of data.

A. In Economic Planning and Control

The idea of using mathematical methods to allocate economic resources for maximum or "optimum" output was discussed by the Soviet Economist Kantorovich[2] as early as 1939. In recent years the

[1] A. I. Kitov and Iu. I. Cherniak: "Avtomatizatsiya upravlencheskikh," Avtomatizatsiya Proizvodstva i Promyshlennaya Elektronika, vol. I, p. 26.

[2] Academician L. V. Kantorovich, formerly at the Leningrad Branch of Mathematics Institute imeni Steklov of the Academy of Sciences, U.S.S.R., is now the director of the Laboratory of Mathematical-Economic Methods of the Institute of Mathematics of the Siberian Department of the Academy of Sciences, U.S.S.R. in Novosibirsk.

increasing complexity of the planning process has engendered active interest in the use of these methods in economic planning. Given valid statistics and simplified economic models, mathematical methods would permit testing draft plans for inconsistencies and imbalances. Implementation of the advanced concept of cybernetic control of the economy, which envisions the drafting of plans, issuing of instructions and regulation of plan implementation down to the enterprise level by computers in a completely automated manner, is not being seriously considered at present. Such a program would require enormous numbers of very fast computers with very large memories. The supply of the necessary computer capacity would be too great a drain on Soviet industrial resources to be practical in the foreseeable future.

Soviet leaders envision the satisfaction of immediate requirements for computers for processing economic information as a result of a program to be initiated in the new 5-year plan (1966–70). According to the chief of the Central Statistical Administration, V. N. Starovskiy, a recent government decree implementing this program provides for the establishment of "a state network of computer centers for the collection and processing of economic information and the solution of problems of planning and control in the national economy." [3] This network will be formed through an expansion and modernization of the existing network of the state statistical system, which has computing centers and machine calculating stations in all Union Republics and oblast and kray centers, as well as more than 650 machine calculation stations in administrative regions and cities. In addition, sectoral and departmental systems of planning, accounting, control, and information processing are to be created as necessary, and connected with the state network.[4] Presumably these sectoral and departmental systems will include the computers in enterprises where the basic economic information is generated in the first instances. The final consolidation and arrayment of economic information for the use of top planners will presumably be accomplished with an economic model of limited size on the computers of the Central Statistical Administration U.S.S.R.

The requirements for equipment for the proposed new network are enormous. In a recent article Dorodnitsyn [5] has estimated that more than 4,000 medium- to large-sized computers would be required. There probably are not more than 3,000 digital computers now installed in the U.S.S.R., of which a very few are so deployed that they would belong to this system. This contrasts with the 28,000 general-purpose digital computers that had been installed in the United States by the end of 1965.[6] Although the Soviets have acknowledged that their computer industry cannot provide all of the equipment needed for the proposed network in 1966–70,[7] even limited progress toward its completion should considerably improve efficiency in data handling at all levels of the economy.

[3] Ekonomicheskaya Gazeta, No. 13, 1966, p. 25.
[4] Ibid.
[5] Academician A. Dorodnitsyn, head of the Computing Center, Academy of Sciences of the U.S.S.R., in an article in Pravda, Feb. 23, 1966.
[6] Electronic Intelligence Digest, Feb. 10, 1966.
[7] V. A. Kirillin, Chairman of the State Committee for Science and Technology, in a speech broadcast from Moscow, Jan. 1, 1966.

B. AT THE ENTERPRISE LEVEL

The need for data processing computers in the producing enterprises is especially great, not only because most of the data for planning and controlling the economy are generated at this level and must be consolidated and transmitted upward, but also because computers can be profitably used for inventory and production control, invoicing, payroll accounting, and the solution of complex engineering problems. The slowdown in industrial growth and in factor productivity in recent years has intensified the interest of Soviet planners in raising efficiency in industry through better management. Naturally, they have turned to the use of computers as a promising means toward this goal. Thus the Collegium of the U.S.S.R. Sovnarkhoz meeting in August 1964 to discuss the introduction of computing equipment and quantitative economic methods into industrial management, concluded that major attention should be given to "the comprehensive mechanization of engineering and administrative labor, including engineering and design calculations, norm [work standards] setting, planning, material and technical supply, economic information, accounting, analysis of production activity, etc." [8] In March 1965, V. D. Lebedev, Deputy Chairman of the U.S.S.R. Sovarkhoz, announced plans to install computers at 119 plants and combines during 1965–66.[9] Only about 100 plants are currently so equipped and these are considered pilot projects.

Large potential gains in industrial efficiency are also inherent in the application of computers to the control of industrial processes. The U.S.S.R. has shown a strong interest in this field, at least since the mid-1950's when a rapid increase in industrial productivity through automation explicitly became an important national goal. Progress in implementing the plans for automation has been very slow, however, in large part because of delays in completing applied research on the processes to be controlled. Among the industrial processes to which computers actually have been applied in the U.S.S.R. since 1957 are chemical and petrochemical production, electric power distribution, steel smelting and rolling, and train dispatching. Although Soviet industry continues to lag far behind the United States in industrial automation, rapid increases in the production of computers together with an intensive program of research on their application in industry are permitting some progress to be made in process control by computers in the U.S.S.R. The new Five Year Plan for 1966–70 places particular emphasis on the need to provide computers suitable for process control.

The requirements for computers in transportation, construction and other service sectors in the U.S.S.R. thus far have been little satisfied. Only a few computers have been installed in these sectors to solve linear programing problems. The success of these initial applications, however, is reflected in plans for greatly expanding the production of appropriate computers.

[8] Ekonomicheskaya Gazeta, No. 37, 1964, p. 37.
[9] Bakinsky Rabochiy, Baku, Mar. 13, 1965.

III. Production of Computers

Although a few digital computers were produced on a laboratory scale in the early postwar years in the U.S.S.R., production on a commercial scale did not begin until about 1957. Consequently, although high rates of increase in output are achieved every year, the shortage of computers remains acute. The following table compares estimated production of computers and data processing equipment in the U.S.S.R. with production in the United States in 1958–65. The comparisons are expressed in value terms. The estimates show that although a higher growth rate prevails in the Soviet Union, the huge lead of the United States in absolute terms has increased every year. The production area at the major computer plants in the U.S.S.R. was greatly expanded during 1959–65 and it seems likely that the high priority now accorded the production of computers will continue.

Comparison of United States and U.S.S.R. production of computers and data processing equipment [1], 1958–65

[Millions of current U.S. dollars [2]]

	1958	1959	1960	1961	1962	1963	1964	1965	Average annual growth rate 1959–65 (percent)
United States	410	490	630	895	1,065	1,240	1,375	1,585	21.3
U.S.S.R.	35	45	55	70	95	120	140	200	[3] 29.3

[1] Neither the estimates of production for the United States nor for the U.S.S.R. include special purpose military computers.
[2] Rubles have been converted to dollars at the rate of 1 ruble equals US$0.75.
[3] This growth rate was computed from unrounded data.

Although in the early years analog computers were dominant, the product mix in the U.S.S.R., as in the United States, is now heavily weighted in favor of digital computers. Most of these are of the general purpose type, although an increasing number of special purpose designs are also coming into serial production for use in industrial planning or process control. The Soviet Union produces very few general purpose digital computers that would be considered large by United States standards. Until 1965, most of the computers produced in the U.S.S.R. resembled those produced in the United States during 1954–60. In 1965, the U.S.S.R. introduced a number of new models of general purpose digital computers, such as the BESM–6, MINSK–22 and MINSK–23, RAZDAN–3, and URAL–11, URAL–14, and URAL–16. Of these, only the BESM–6 and URAL–16 can be considered large-size computers by U.S. standards.[10] Most of these

[10] Electronic News, June 7, 1965. Prof. Andrei P. Yershov, head of the Programing Department of the Computer Center, Siberian Division, Soviet Academy of Sciences, Novosibirsk, described the new computers at a meeting of the Association for Computing Machinery in Culver City, Calif., in June 1966. The BESM–6 has a core memory of 16,000 to 32,000 words of 48-bit length and an access time of 2 microseconds. A high degree of parallelism permits an average performance of 1 million instructions per second. The computer will cost about 3 million rubles and can be used for time sharing operations. He described the URAL–16 as having both fixed and floating decimal point, a 48-bit word length, 50,000 operations per second, a core memory of 8,000 to 64,000 words, memory access time of 9 microseconds, and a drum memory of 130,000 words.

new computers embody the memory size, high operating speed, and peripheral equipment necessary for data processing applications and represent a significant advance in both technology and capacity. The BESM–6, which has operating characteristics somewhat similar to those of the IBM 7090, is the largest and fastest known Soviet computer, and is claimed capable of averaging 1 million operations per second. This model is not likely to be generally available in significant numbers in the next year or two, however. The URAL and MINSK machines are typical of the new medium-size computers that are likely to be available for data processing uses in the immediate future.

The first transistorized computers were not introduced in the U.S.S.R. until 1961–62, in contrast to 1958–59 in the United States. Although all models of Soviet computers produced since early 1964 have been transistorized, production of the outmoded electron tube-type computers was not completely discontinued until 1965. There are no indications that the U.S.S.R. yet produces third generation computers, i.e., those with integrated circuitry, which represents the latest state of the art in the United States. In fact, the development of the integrated circuit components for such electronic computers was only recently identified by a high Soviet spokesman as a major assignment for the electronics industry in the plan for the next 5 years.[11]

A dearth of peripheral equipment has persistently plagued the users of Soviet computers for data processing. This shortage is a consequence of the long delay in recognizing the need for computers to perform data handling tasks. The peripheral equipment described in connection with the digital computers introduced in 1965 includes auxiliary memories of magnetic tape and drum types, improved page and line printers, and better punch card and paper tape readers. Unfortunately for the U.S.S.R., the quality of this peripheral equipment still leaves much to be desired. Dorodnitsyn [12] considers the lag of Soviety technology in this area to be too great to be satisfactorily overcome in an acceptable period of time through domestic research and development. He therefore recommends importing the necessary equipment or obtaining licenses to produce it. He reasons that the cost of acquiring it in this way probably would not greatly exceed the cost of domestic production (including research and development costs) and that any additional costs that might be incurred would be justified by the resultant shortening of the delivery period for the initial equipment.

Continued rapid growth of the Soviet computer industry is dependent on the availability of investment capital, components, and trained labor. Availability of capital does not appear to be a restraint to the growth of the industry, which has been accorded a high priority. The problem of the supply of components probably has been somewhat eased recently by the rapid growth in the production of semiconductors, which reportedly increased by 40 percent in 1965.[13] The provision of the skilled labor required for computer production has

[11] V. A. Kirillin, op. cit.
[12] Academician A. Dorodnitsyn, op. cit.
[13] A. I. Shokin, Minister of the Electronics Industry, Izvestiya, Jan. 4, 1966.

been a persistent problem that is likely to continue. The necessity for using labor with inadequate skill tends to reduce productivity in the Soviet computer industry and to contribute to a low quality product and excessive maintenance costs for the user.

IV. Institutional Problems

Several factors inherent in the organization and operation of the Soviet economic system tend to preclude optimum application of computers. As is typical of Soviet industry in general, emphasis has been put on series production of a minimum assortment of standardized models of computers, rather than on the production of computers tailored to requirements of particular consumers. Moreover, when a standardized computer has become obsolete and a replacement model more responsive to user needs has been developed, the production of the obsolete model usually continues for an excessively long period. This situation, which is chronic in the Soviet machine-building industries, stems in large part from the fact that the production loss incurred by a plant in changing models typically leads to losses of bonus payments to the management and the work force. Delay in the appearance of improved models also occurs as a result of the bureaucratic separation of computer users, producers, and designers. This situation can be contrasted with that in the United States where the producer not only is also the designer, but frequently has his representative physically present on the user's premises to maintain the computer and provide direct liaison between user and designer.

In the U.S.S.R., very few services accompany the sale of a computer. The customer receives brief instruction in programing, operating, and maintaining his computer, but once it has been installed the manufacturer takes no further responsibility for its maintenance. Spare parts are often unobtainable from the computer manufacturer and even from component manufacturers, and the user is forced to employ makeshift expedients to keep his machine operating. Such makeshift repairs may change the operating characteristics of the computer enough to prevent the sharing of programs among users of the same model.

Even before the recent decree for establishing a state network of computer centers was announced, measures to correct some of these deficiencies had been undertaken in the U.S.S.R. As recognition of the seriousness of losses in computer working time became greater, several governmental bodies were established to investigate difficulties in the utilization of computers, to make suggestions for further research and to oversee servicing arrangements. At the national level, representatives of the Ministry of the Radio Industry, the Ministry for Instrument Making, Means of Automation and Control Systems, and the State Committee for Science and Technology confer among themselves and with representatives of the Academy of Sciences and of the Ministries in which computers are employed, in order to decide which newly developed models should be scheduled for production. At the Republic level, computer producers, design institutes, and computer users have been formed into production-engineering associations, with the intended purpose of advising one another on the problems of planning, designing, producing, installing, and using the computers located in the particular republic.

The production-engineering organizations and the scientific research institutes play a major role in the job of assimilating computers into the economy. Between them, they carry out the function performed in the United States by manufacturers' sales and service representatives and by private data processing service organizations. In the last few years several new cybernetics institutes and economics-engineering institutes have been founded in the U.S.S.R. to create computer programs, perform systems engineering for process control applications, design forms for economic reporting, and train applications and programing personnel.

According to Starovskiy,[14] these efforts are to be intensified and expanded under the provision of the decree on the state computer network. The decree states that installation, adjustment, and putting into operation of the systems and equipment of the state computer network will be contracted out to a new organization, the All-Union Planning and Installation Administration, under the Ministry of Instrument Making, Automation Equipment, and Control Systems. This administration is to have a network of territorial planning sections and installation administrations and will maintain cost accounting on its operations. The Ministry of the Radio Industry is charged with the installation, adjustment, putting in operation, and servicing of all computers and accessories that its enterprises produce. Apparently, the All-Union Planning and Installation Administration is to have a general contractor's role on total systems and the Ministry of the Radio Industry is to be held responsible for the installation and correct functioning of the computer equipment that it manufactures. Inasmuch as the computer centers are to keep books on their operations, they probably will pay computer producers for servicing the computers. Such a system would insure that service would be rendered. On this same theme, Dr. O. Kozlova,[15] professor of economic sciences, recently proposed that automatic data processing equipment be leased to enterprises, with the manufacturer assuming full responsibility for installing, adjusting, and maintaining it. This is the most common marketing arrangement between the producers and users of computers in the free world.

The Soviet propensity for maximizing physical production rather than satisfying users' needs has resulted in the design of computers that are difficult to use. Soviet computers generally cannot accept instructions in timesaving "programing language" (such as FORTRAN), and the Soviets have not provided the input-output equipment needed for the use of the automatic language compilers and translators that are standard in U.S. practice. Soviet programers have had to prepare instructions in numerical form, a time-consuming process. Moreover, the U.S. practice of providing computer users with standard programs for frequently run problems is seldom employed in the U.S.S.R., with the result that much time is spent in redundant programing work. Recently, some steps have been taken to correct these deficiencies. Language compilers for some of the new computers are being developed, a central repository for programs for mathematical problems has been created at the State Scientific and

[14] V. N. Starovskiy, op. cit.
[15] O. Kozlova, Pravda, Mar. 4, 1966.

Technical Library, and several economic research institutes are compiling standard programs for common accounting and control problems in commerce and industry. By terms of the decree establishing the state network of computer centers, responsible departments and scientific institutions are to continue this work and to provide libraries of standard programs, autocodes, and algorithmic language translators. These programs will, of course, depend on the provision of the necessary input-output equipment.

The efficient use of computers is impeded in the U.S.S.R., not only because of the lack of conveniences for programers, but because of a severe shortage of qualified personnel for maintenance and programing. Technical and economic institutes have established courses to train people in these skills, but enrollments continue to be inadequate to meet even the present requirements. Unless training programs are rapidly stepped up, a severe shortage of skilled personnel is likely to exist when the expected rapid increase in the installation of electronic data handling equipment occurs.

The U.S.S.R. recognizes the value of the wide application of computers in the economy not only as a means of significantly reducing the cost of economic planning and management, but also as a means of retarding the rapidly mounting rate of absorption of manpower into data-handling tasks. Soviet planners realize that they are tardy in developing the technology for applying computers to data processing. Although this matter has been given great emphasis in the directives for the next 5-year plan (1966–70), Soviet leaders also explicitly acknowledge that the task cannot possibly be accomplished in such a short time. In view of the fact that military/space activities have first claim on available computers, that many others are needed by various kinds of priority scientific institutes, and that many existing models are of obsolete design, slow, and difficult to maintain, providing the Soviet economy with adequate data-processing equipment must indeed be viewed as a protracted task.

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