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NEW TECHNOLOGY IN THE AMERICAN MACHINERY INDUSTRY: TRENDS AND IMPLICATIONS

A STUDY

PREPARED FOR THE USE OF THE

JOINT ECONOMIC COMMITTEE
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LETTER OF TRANSMITTAL

February 9, 1984

To the Members of the Joint Economic Committee:

I am pleased to transmit a study entitled "New Technology in American Machinery Industry: Trends and Implications." This study was commissioned by the Joint Economic Committee and written by Dr. John Rees of Syracuse University and Dr. Ronald Briggs and Dr. Donald Hicks of the University of Texas at Dallas.

The industries in this study are producers of metal-working machinery, industrial apparatus, construction machinery, fabricated metal products, and electrical equipment. They constitute a significant part of America's industrial base and are concentrated in the Nation's industrial heartland.

This research shows that despite the absence of targeting schemes these industries are responding to powerful market forces to improve productivity and remain internationally competitive through innovation and the use of advanced technology. Consequently, it disputes a popular view that our country is segregating into "high-tech" regions which are prosperous and "low-tech" regions that are dying.

America's older, basic industries are using advanced production methods to rejuvenate themselves. In turn, they are providing opportunities for suppliers, subcontractors, and support services. These results should be noted by those who maintain that a "targeted" industrial policy is needed to help older industries and regions become competitive lest they hinder industrial rejuvenation and technological innovation. The authors of this study correctly note that the best governmental response to a changing industrial climate is to remove regulatory barriers to technological innovation and to adopt policies that encourage capital formation. With the correct policies America's basic industries will re-industrialize by themselves.

Sincerely,

ROGER W. JEPSEN
Chairman, Joint Economic Committee

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New Technology in the American Machinery Industry: Trends and Implications

by

John Rees, Ronald Briggs and Donald Hicks*

A study prepared for the use of the Joint Economic Committee, Congress of the United States

September 1983

*The authors are respectively Associate Professor of Geography, Syracuse University; Associate Professor of Geography and Associate Professor of Sociology, University of Texas at Dallas. The authors wish to thank Dr. Raymond Oakey, Mr. Larry Patrick, Ms. Pamela Van Cleve, Ms. Florence Cohen and Mr. Akbar Torbat for their assistance at various stages of this research. The financial support of the National Science Foundation (NSF grant SES 8105882) and the University Computing Company (Dallas, Texas) is gratefully acknowledged for funding the original research on which this paper is based. The interpretations and conclusions expressed herein are the authors' and in no way reflect the views of the funding agencies.

Summary and Implications

The purpose of this study is to draw attention to the prospects for rejuvenation of one of America's most vital industries, metalworking machinery, and the regional economies which it anchors. The study was based on the premise that the process of technology-upgrading in pursuit of increased productivity and enhanced competitiveness may well hold the promise of future industrial and regional recovery.

The study discusses the results of two projects that examined the spread of a number of key production technologies among metalworking machinery industries across the country. The first project examines the adoption of automated machine control and handling systems, the use of computers and microprocessors within a limited number of metalworking industries. Based on a survey of nearly 4000 individual plants this project showed that:

- Plants affiliated with multi-plant firms are much more likely to use these new technologies than single-plant firms. Larger plants also show consistently higher rates of adoption.
- Older, more established plants are more likely to use these technologies than newer plants
- Plants with more Research and Development work located on-site are more likely to adopt these new technologies
- Regional differences are evident in the patterns of adoption. User rates for these new technologies are generally higher in the industrial Midwest than they are in the new growth regions of the South and West. Adoption rates are also generally higher in urban as compared to rural locations.
- Significant regional differences in adoption rates occur for single-plant firms but not for multi-plant firms. Single-plant firms located close to areas

where the technologies were developed are more likely to use these innovations than similar firms in distant regions.

. A relatively rapid spread of these innovations took place during the 1960s and 1970s, and this diffusion pattern did not seem to be affected by downturns in the business cycle.

The second project focuses on the adoption of one family of technologies: numerically controlled and computerized numerical control systems among nearly 1200 small plants (those employing less than 250 employees) in the metalworking industry. This project was primarily concerned with reasons why these technologies were adopted and their labor impact. Some of the major findings of this survey were:

. The innovation adoption decision among these plants is primarily driven by the desire to increase plant productivity levels and by the perceived need to improve a plant's competitive position. The urge to compensate for a shortage of skilled workers or to engage in a strategy of labor substitution in order to adjust to or put downward pressure on wages does not figure prominently in the motivations of plant managers to adopt such advanced production technologies.

. One plant in four planned to proceed with automated machine control plans and to do so in the near future. This would significantly increase the amount of automation throughout the broad, small plant end of the machinery industry.

. The metalworking industry has been severely hit by the recent recession, with employment contraction experienced in most regions of the country. Among this sample of small plants, the older ones were more likely to experience employment contraction than younger plants. Plants with unionized production workers likewise experienced higher rates of employment contraction than did nonunion plants.

Policy Implications

Though neither of these projects included a direct examination of the impact of existing government policies on the metalworking machinery industry *per se*, the findings do have a number of important policy implications.

(1) The results of both projects offer strong evidence that conventional market mechanisms are indeed working in the sense that retooling is taking place as firms adopt the latest available automation technologies. Such retooling is viewed as mandatory for firms to remain competitive in the international marketplace. Despite the absence of explicit, targeted policies aimed at investment within the older industries and regions examined in this study, both industries and regions reveal a potential to rejuvenate and recover.

The two surveys were not meant to include an evaluation of recent cost recovery options for business, such as the Accelerated Cost Recovery System included in the Economic Recovery Act of 1981. But the findings do suggest that faster cost recovery options would spur further adoption of automated capital equipment, particularly among larger multi-plant firms. Indeed, the accelerating spread of these technologies throughout the 1960s and particularly the 1970s suggests that the innovation adoption decision is part of a long term strategic planning policy among industrialists that overrides short term considerations imposed by the business cycle.

Since the first project shows that rates of innovation adoption were higher among larger multi-plant firms than single-plant firms, the findings of the study suggest that federal tax and regulatory policy ought to be even-handed and designed to remove any bias against small business. Because significant regional differences in adoption rates among single-plant firms indicate that firms located close to areas where the technologies were developed are more likely to use these innovations, this suggests that state and local governments may wish to consider business development policies to facilitate the spread or diffusion of innovations among small firms.

(2) Not only do the findings of these surveys suggest that industry revitalization is more market-driven than policy-driven, the findings of the second survey in particular suggest that the spread of new machine control technology to small and medium sized firms was technology-driven as well as market-driven. Since small firms in the metalworking industry were able to obtain technologies tailored to fit their special needs both in size and price for the first time, this suggests that small plant managers did not need special nonmarket inducements to step up their level of technological sophistication. Here innovation adoption decisions were primarily tied to the availability of technology, where computerized machine control systems in particular had moved through their technology life-cycle to a point where they could filter into the least-accessible small firm end of the industry.

(3) Since these surveys find that industry renewal rests on technology-upgrading to a considerable degree, barriers to such upgrading should be the subject of intensive policy concern. If one such barrier is the chronic problem of a shortage of skilled labor in the machinery industry, then higher priority should be given in both the private and public sectors to a human capital strategy that emphasizes labor training and retraining programs. Such programs can again form part of state economic development strategies.

Another barrier to technology-upgrading may lie in the regulatory environment, particularly pertaining to anti-trust. The relaxation of anti-trust constraints and similar regulatory impediments would serve as an incentive for companies, particularly smaller ones, to conduct joint R and D projects which would be prohibitively expensive to conduct individually.

Because of the evolution of many of the technologies studied from explicit government-university research contracts, increased incentives for industry-university R and D ventures can only help to accelerate the process of technology upgrading. Since both of the projects reported in this study found one of America's vital industries, the metalworking machinery industry, to be well placed on a trajectory of rejuvenation and recovery, the removal of barriers to technology upgrading should be of primary concern to policy-makers in both the private and public sectors. This study therefore underlines the importance of Congressional efforts to encourage the industrial innovation process as a way of rejuvenating and sustaining the economic health of the country.

1. Introduction

The industrial restructuring and adjustment taking place in the nation today have recently been the objects of widespread and conflicting policy prescriptions. Recurring recessions through the 1970s and early 1980s have heightened the visibility of the decades-long "shift to services" and the recent surge of employment growth in high-technology industries. This has had the curious effect of encouraging many to underestimate the resilience and potential retained by older basic industries. As a consequence, some advocate the adoption of more explicit industrial, trade and technology transfer policies in order to ensure that this economic restructuring unfolds in an orderly fashion, while others advocate a role for public policy that clears the way for market-oriented adjustments rather than attempting to choreograph more complex political ones. Those concerned with the social welfare and community dimensions of this transition likewise array themselves along a similar policy continuum.

While single-factor theories of industrial change are properly suspect, a great deal of attention has been accorded both science and engineering and their derivative technologies in their roles as catalysts of industrial rejuvenation. The industrial restructuring of the U.S. currently underway is commonly assumed to be driven, at least in part, by the diffusion and adoption of new technological capabilities. As a consequence, in the wake of such technological change many view the industrial landscape as being increasingly divided into "hi-tech" and "low-tech" production arrangements, the nation's economic landscape as being divided into prospering and "dying" regional and local economies, and the generations of workers as being segregated by whether or not their skills are appropriate to the range of tasks that will dominate and define the emerging new industrial economy. Most disturbing of all is the fear that these three patterns will be highly correlated resulting in older industrial sectors, areas and workers being locked in a mutually destructive embrace while industries and workers in regions elsewhere are destined to grow and prosper.

The tradeoffs between enhanced productivity and international competitiveness and employment and security predictably accompany our passage through and exit from older industrial arrangements. However, while scientific advancements and technological innovations will surely figure prominantly in the economic growth of new industries and new localized economies in the future, the adaptation of advanced design, production, and related manufacturing technologies to older industrial arrangements likewise promises to revitalize from within the existing industrial base of the nation. Revitalized older industries--and perhaps too the regions in which they are located--can be expected to take their place alongside wholly new industries and regional economies in defining a new and advanced industrial era. Older arrangements may not so much be jettisoned and discarded as reorganized and thereby restored to higher, if not historical, levels of usefulness. Evidence of this prospect is what this study offers.

Our purpose is to examine differences in the spread of key production innovations and their labor impact in various machinery industries across the United States leading to an examination of policy alternatives that would encourage further economic growth across the country. Just as the rate of technological change can be directly related to economic growth at the national level; so can the innovation level of states and metropolitan areas be related to their growth rates. Indeed, state and metropolitan differences in manufacturing productivity may be related to the failure of plants in some areas to adopt the latest production innovations.

This study will examine the implications of two research projects that analyze the spread of key production innovations in manufacturing. The first project examines the spread of major production innovations related to the use of automated machine control systems, the use of computers, programmable handling systems and microprocessors among machinery manufacturers across the United States. All these techniques relate to the degree of automation in manufacturing and will have substantial impacts on employment levels in the long run in terms of both new and existing jobs. A questionnaire survey was sent out to nearly 4000 manufacturing plants across the country and responses allow us to relate technology adoption rates to a number of variables: industrial sector, organizational type (single and multi-plant firms), size and age of plant, the amount of Research and Development activity carried out, and locational characteristics of the plant.

The second project focuses on one of these innovation sets, the use of new machine control systems and reports on a survey of 8000 small plants in the metalworking machinery industries across the country. This project examines the factors which influence the decisions to upgrade production technologies in small metalworking plants and explores the patterns by which these technologies have spread throughout the industry. In addition, this report explores the labor and employment implications associated with the succession of technology from conventional to more sophisticated and automated forms of machine control. An attempt is made to understand the extent to which the factors that make an industry vulnerable to employment loss might also be the same as those which set the stage for increasing automation.

From the results of this second survey it is possible to explore the ways in which the upgrading of production technology throughout the small plant base

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of a vital industry can serve as a vehicle for industrial renewal and rejuvenation. As the United States gears up for economic recovery after a prolonged period of recession, and as the structure of the economy continues to change, the results of these two projects allow us to identify factors and policy initiatives that may sustain the growth of the national economy by encouraging the spread of new technologies throughout American industry.

2. Background

2.1 The Metalworking Machinery Industry as a Setting for Change

To study change in the U.S. metalworking industry is tantamount to studying this nation's adaptation to the urban-industrial era itself. The evolution of the metalworking industry over the past two centuries reflects not only the gradual domination of the U.S. economy by manufacturing but also the increased mechanization of production and its dependence on metal products and tools which basic manufacturing processes have come to require (Rosenberg 1972).

Today, the metalworking industry is multifacted and serves as an umbrella for a wide variety of disparate industries including the primary and fabricated metal industries, the machinery and electronic equipment industries, and the transportation and instruments industries, among others. While a common denominator for all these industries is the fact that the medium for manufacture is metal, long years of product differentiation and process development have created an overall industry which is today highly variegated.

Yet, beneath this seeming diversity lurk several enduring characteristics which suggest an industry at-large which is slow to change. As the metalworking industry has evolved, certain structural features have operated to constrain its modernization. Since the industry is bottom-heavy with thousands of small plants and shops, existing technologies have either not been available to handle tasks at an appropriate scale for such industrial settings or their productivity gains have not been sufficiently attractive relative to the front-end investment requirements. In short, the "re-wiring" of plants and shops throughout the metalworking industry has proceeded slowly at best, at least until the 1970s. As the next section of this report shows, however, older plants within the metalworking machinery industries show a high propensity recently to adopt new technologies, and thus display a latent potential for future retooling and rejuvenation.

2.2 Advanced Technology Adoption in the Metalworking Industry

A recent study by the Office of Technology Assessment (1983) reported that the manufacturing sector of the economy is poised to experience sweeping changes attributable to the adoption of programmable automation capabilities such as is found in robots, computer-assisted planning, design and manufacturing (CAD/CAM). Yet, though the harnessing of computers to manufacturing and design processes is not new, until recently the diffusion of such technological sophistication to and through plants and shops has been limited to those firms which are established and large enough to accommodate the typically heavy entry investment (see Section 3).

Today, due to lower production costs, the recent development of scaled down turnkey systems of machine control, the present need to accommodate long-term shortages of workers with appropriate skills, competitive pressures in localized economies, and contractual stipulations that frequently require ever greater quality control, newer technologies strike a better "fit" to thousands of plants for which they were previously inappropriate. With the availability of relatively inexpensive CAD/CAM systems, many new technologies are now within the reach of strata of medium-sized and small manufacturing and engineering firms (Bylinsky 1982). It is apparent that much advanced manufacturing technology which has been available in principle for many years is now filtering down through the metalworking industry after having long been hindered from doing so.

2.3 The Geographical Patterns of Industrial Development

The geographical concentration of the metalworking industry throughout the Industrial Heartland--especially the East North Central and Mid Atlantic Census divisions--cannot be ignored. From Table 2.1 we see that 52 percent

TABLE 2.1

GEOGRAPHICAL DISTRIBUTION OF METALWORKING INDUSTRY

	N	N	%
New England		790	9.8
Maine	25		
New Hampshire	60		
Vermont	14		
Massachusetts	390		
Rhode Island	37		
Connecticut	264		
Middle Atlantic		1571	19.7
New York	596		
New Jersey	391		
Pennsylvania	584		
East North Central		2574	32.2
Ohio	762		
Indiana	241		
Illinois	711		
Michigan	573		
Wisconsin	287		
West North Central		621	7.8
Minnesota	219		
Iowa	80		
Missouri	188		
North Dakota	4		
South Dakota	17		
Nebraska	30		
Kansas	83		
South Atlantic		546	6.8
Delaware	4		
Maryland	67		
Washington, D.C.	1		
Virginia	67		
West Virginia	24		
North Carolina	130		
South Carolina	55		
Georgia	48		
Florida	150		
East South Central		193	2.4
Kentucky	63		
Tennessee	71		
Alabama	47		
Mississippi	12		
West South Central		481	6.0
Arkansas	29		
Louisiana	33		
Oklahoma	89		
Texas	330		
Mountain		221	2.8
Montana	1		
Idaho	3		
Wyoming	2		
Colorado	76		
New Mexico	19		
Arizona	73		
Utah	38		
Nevada	9		
Pacific		997	12.5
Alaska	1		
Washington	87		
Oregon	52		
California	857		
Hawaii	-		
Total		7994	100.0

Source: Compiled from Modern Machine Shop (Cincinnati), American Machinist (New York) and County Business Patterns (U.S. Bureau of Census) of all plants in the industry are located in these two regions that make up the traditional heartland of American manufacturing. Furthermore, the industry as a whole is tied into a dense network of suppliers, subcontractors and industrial customers, some of which are themselves highly localized. This pattern of concentration tends to amplify the consequences of intra-regional competition and the job and market losses associated with industrial restructuring. Moreover, the industry remains sensitive to the relatively low value-to-weight ratios of its products that quickly translate into high transportation costs among plants and shops which work with metal. In a sense, then, the locational immobility of the industry has been matched at least within smaller plants by a comparable immobility with respect to the transformation of productive arrangements inside the plants.

While the industry appears to have risen slowly from its Mid Atlantic and New England regions of origin, following World War II and coincident with the industrial development of the band of states from New York west to Illinois, the pace of industry expansion in the East North Central region surpassed that found elsewhere, and this continued through the 1970s. The expansion within the Middle Atlantic region paralleled that of the East North Central until it began a relative decline after the 1960s.

The growth in the Far West--notably California--was largely a post-WWII phenomenon, yet it was eclipsed in each decade by that in the East North Central and Middle Atlantic regions. Finally, the growth in the South (i.e., South Atlantic, East South Central and West South Central) generally came later than that in the Far West. As the South gradually became the manufacturing center--and after 1960 eclipsed the West as the population growth pole--of the nation, the metalworking industry likewise filtered into the South. Yet, like the West, the South has never seriously challenged the Industrial Heartland for dominance in the metalworking industry.

The new plants of successive birth cohorts have largely been captured by the older industrial regions. Of the 207 new plants in the 1950s cohort, the 326 plants in the 1960s cohort and the 318 plants in the 1970 cohort, respectively 57 percent, 47 percent and 43 percent were captured by the East North Central and Middle Atlantic regions. Even during the recession-plagued 1970s and early 1980s, the older industrial regions continued to spawn new plants with 43 percent of those in the 1980s being located in the East North Central region alone (Hicks 1983).

Therefore, the Industrial Heartland appears to have more than held its own in terms of the upgrading of the metalworking industry through new plant growth. In these data there is little to support the common speculation that older industrial regions are less susceptible to renewal and rejuvenation through new industrial growth and expansion. An industrial metabolism has indeed altered the structure of the metalworking industry, as this study discusses, but it has largely done so within its original industrial seedbed.

2.4 Automation and Employment Change

From the machine tool industry at its center to a whole host of satellite and interdependent industries--including the linked industrial sectors commonly referred to as the metalworking industry--the nation's industrial complex and a whole host of institutions tied to it have been faced with the need to abide and adjust to rather than resist the changes which promise to transform dramatically the nation's economy.

Special scrutiny and concern have been directed not only to the relatively slow growth in the manufacturing sector, but also to the increased incentives for labor substitution which further dampen employment growth in manufacturing. It is here that the role of automation invites special attention. While the adoption of ever more sophisticated technologies and their diffusion throughout entire industries is centuries old, its potential for massive job displacement has periodically generated bursts of deep concern. The celebrated misgivings of the Luddites about mechanized production in the textile industry notwithstanding, there is historical evidence that, on balance, automation generally has been induced by incentives to maximize production efficiency rather than to displace labor per se (Ferguson 1981). However, that was before skilled labor necessarily implied relatively high wages insulated from adjustment to changing market conditions by strong industrial unions.

It has been suggested that automation could bring about a major reduction in the factory workforce over the next ten years. Yet, in the metalworking industry this general prophecy needs to be more carefully qualified. Given the chronic shortage of skilled machinists available for conventional machine control operations, a surge of automation is not expected to generate as much job displacement in machining as in actual fabrication and assembly (Bylinsky 1982).

Even so, it was not until the recent recession and the forecast of widespread and permanent job loss that the full weight of concern about automation has come to be felt. For some the falloff of investment in capital equipment since the 1960s appears to belie any accelerated trend toward greater automation. Yet, the visibility of factory closings and the estimates that private disinvestment by American business resulted in the loss of 30-40 million jobs in the 1970s alone has revived widespread anxiety over the role of automation in industrial change (Bluestone and Harrison 1982).

3. The Adoption of New Production Technologies

3.1 Research Design

In the first study discussed in this report, a discrete number of product and process innovations within manufacturing were selected as the focus of investigation.[1] All the innovations relate, directly or indirectly, to computerized automation within manufacturing and represent a set of techniques at differing levels of sophistication that may have a significant long-term impact on the American labor force and on productivity levels. The innovations selected relate to four main areas of production technology: machine control, the use of computers, handling systems and the use of microprocessors.

The specific techniques examined are:

- numerical machine control (NC) devices
- computerized numerical control devices (CNC)[2]
- computers used for commercial activities only, e.g. invoicing, stock control, accounting
- computers used for design and drafting activities
- computers used in manufacturing (excluding CNC)
- programmable handling systems for materials and subcomponents, including numerically controlled pick-up-and-place devices and simple programmable robots
- non-programmable handling systems for materials and components, including manual and non-programmable pick-up-and-place devices

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[1] This part of the report draws upon a study by J. Rees, R. Briggs and R. Oakey: The Adoption of New Technology in the American Machinery Industry, Discussion Paper, Syracuse University, based on a project funded by the National Science Foundation NSF grant SES 8105882. This is part of an international collaborative research project involving the United Kingdom and the Federal Republic of Germany under the coordination of Professor John Goddard.

[2] NC machines are controlled by programs expressed in numbers, and are predecessors (on the road to fully flexible automation in manufacturing) of the more flexible and versatile CNC systems which are the equivalent of NC machines equipped with programmable computers.

- the use of microprocessors, mini- and micro-computers in the final product of a plant.

The first six production techniques relate directly to increased automation in the production process. Non-programmable material handling systems were included to isolate plants with more traditional handling devices. The use of microprocessors in the final product was the only product innovation examined.

The selection of innovations for study and the choice of industries as potential adopters were inter-related issues because the choice of innovation suggests particular sectors, for example, the use of NC and CNC suggests the metalworking machinery industry. Furthermore, to limit the scope of the study, and to facilitate inter-regional and international comparisons, it was necessary to clearly delineate a number of industries (by 3 and 4 digit SIC classification) as candidates for adopting the above innovations. The choice of a limited number of target sectors also acts as a control for industrial structure and how it influences technology utilization levels.

The six target sectors chosen were producers of:

- farm machinery (SIC 3523)
- construction and related machinery, including elevators, conveyors, cranes, industrial tractors (SIC 3531, 3534, 3535, 3536, 3537)
- metalworking machinery for cutting and forming (SIC 3541, 3542)
- electrical distributing equipment, including transformers and switchgear (SIC 3612, 3613)
- electrical industrial apparatus, including motors, generators and welding equipment (3621, 3623)
- aircraft and parts, including engines (3721, 3724)

Most of the target population of potential adopters, amounting to 94 percent of respondents, were machinery manufacturers (SIC 35 and 36). Thus, the study was restricted to integral parts of the capital goods sector.

A postal questionnaire survey was sent to 3873 individual manufacturing plants in the target sectors employing over 20 people as identified in the DUNS files of the Dun and Bradstreet Corporation* (1976). The questionnaire was sent out between February and April 1982 to all plants across the U.S. identified in the DUNS files as producing goods with the above SIC codes. This ensured extensive geographical coverage of the United States, as suggested in Table 3.1. Plants employing less than 20 people were left out of the survey because past research has shown high death rates and lower response rates from this group.

A total of 628 completed responses were obtained. When undelivered questionnaires were discounted (either because the plant had moved to an unknown address or gone out of business) this response represented an adjusted rate of 20 percent. This response rate is particularly good when compared with other studies of this kind when success depends on the cooperation of busy corporate executives.

Because a major purpose of this study was to examine differences in innovation adoption across a limited number of industrial sectors, it was particularly important that respondents to the mail survey represented a random geographical sample. A chi-square statistic of 13.12 showed no significant difference between the proportion of responses compared to the total population, i.e. the responses were random geographically.

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*Though the accuracy of Dun and Bradstreet data has been questioned in studies of job creation, it remains the best national directory of manufacturing establishments available on computer tape.

Table 3.1 POTENTIAL ADOPTERS BY INDUSTRY AND REGION

SECTOR	N.E.	N.C.	S.	W.	US.
AGRI MACH	24	411	164	96	695
MACH TOOLS	222	452	72	89	835
CONSTR EQUIP	53	211	108	56	428
MECH HANDLING	156	357	153	117	783
ELEC MACHINERY	234	354	177	125	890
AIRCRAFT AND PARTS	63	54	63	62	242
TOTAL	752	1839	737	545	3873

Data Source: Dun + Bradstreet
(plants > 20 empl.)

3.2 Results

Tables 3.2 through 3.8 show the rates of adoption of the eight technologies according to the various characteristics of the manufacturing plants surveyed. Adoption rates (percentages) are displayed and chi-square tests of statistical significance* were run on the absolute number of adopters per cell.

3.2.1 Adoption Rates by Industrial Sector

Table 3.2 shows adoption or user rates by industrial sector, using the 3 digit SIC code of the U.S. Census. Thus, of the 132 makers of agricultural machinery in Table 3.2, 20 percent had adopted numerically controlled machines in their production process. When differences in adoption rates are analyzed by industry, using a chi-square test, there are statistically significant differences (Table 3.2) in the adoption patterns, but only for five out of the eight technologies. These differences are discussed below according to the four major groups of techniques surveyed.

(i) The Use of Machine Control Systems

The use of numerically controlled machinery varied from a 20 percent adoption rate among producers of agricultural machinery to a 68 percent adoption rate among aircraft manufacturers. The same general pattern is true for the use of computerized numerically controlled machinery.

In four of the six industries the adoption rate for CNC was higher than that for NC, suggesting that companies who had adopted NC also opted for the more advanced production technology. CNC is a major step in what Nelson and

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*The chi-square test is one of the most common analytical comparisons applied to multiple groups of data classified as frequencies. The result tests whether the observed frequencies of a given phenomenon (in this case adopters of particular innovations) differ significantly from the frequencies which might be expected (in this case from the general distribution of industry).

Table 3.2 ADOPTION RATES BY INDUSTRIAL SECTOR

	FARM MACH (352)	CONSTR MACH (353)	METAL WORK MACH (354)	ELEC DIST EQUIP (361)	ELEC IND APPAR (362)	AIR-CRAFT (392)	χ^2	PROB
NC	20	43	58	23	36	68	65.5	SIG .0001
CNC	23	37	58	27	44	70	54.6	SIG .0001
COMPUTER FOR COMMERCIAL	63	69	61	67	62	82	6.9	.228
COMP FOR DESIGN	10	21	19	36	28	51	36.6	SIG .0001
COMP FOR MFG	34	49	46	41	40	55	8.7	.122
PROG HANDLING	4	6	5	8	7	18	10.1	.07
NON-PROG HANDLING	47	45	36	48	46	68	14.2	SIG .014
MICROPROC IN PRODUCT	11	21	41	23	28	31	34.7	SIG .0001
TOTAL # of RESPONDENTS*	132	170	152	77	57	40		

*The number of respondents are not necessarily the same for each technique due to a limited number of missing values.

Winter (1977) call the natural trajectory of technological evolution from, in this case, manual control systems to advanced forms of automated production.

The aircraft industry stands out as the major user of both NC and CNC largely because the Department of Defense, and the U.S. Air Force in particular, have played a major role in the development of automated production through its ICAM, i.e. integrated computer-assisted manufacturing program (National Research Council 1981).

The metalworking machinery industry has adoption rates over 50 percent for both NC and CNC systems probably because companies in that industry were the most directly involved in the generation of that technology (Rosenberg 1972).

(ii) The Use of Computers

When adoption rates for the use of computers for commercial activities are examined by sector, no statistically significant differences are evident. Adoption rates greater than 60 percent of all plants are evident in all six industries, and reach 82 percent in the aircraft industry. This is not an unexpected pattern, given that one might expect most companies today to use computers on site in their non-manufacturing activities, for accounting, invoicing, or payroll functions.

When one examines the use of computers for design, on the other hand, adoption rates are much lower and the difference between sectors is statistically significant. Again, the aircraft industry is the most innovative in its adoption of computers for design purposes (51 percent), while the makers of farm machinery are the least innovative here. The use of computers in the manufacturing process per se (excluding CNC) is more widespread than for design, but a statistically significant pattern is not evident between industries.

(iii) Handling Systems

The rate of adoption of programmable or computerized handling systems is low in all sectors, with user rates below 10 percent in five out of the six industries (the exception being aircraft). Because the development of robotic handling systems is still in its infancy this pattern is not unexpected. On the other hand, the use of non-programmable (i.e. manual and mechanical) handling systems is more widespread throughout all the sectors in Table 3.2 with five out of the six showing adoption rates above 40 percent.

(iv) Use of Microprocessors in Final Products

The use of microprocessors as components in the final products of the plants surveyed (a product as opposed to process-oriented innovation) shows statistically significant differences between sectors. The most innovative sector in this regard is the metalworking machine tools industry, which has increasingly used microprocessors in its products over time, as shown by the development of computerized numerical control systems by the industry. The second largest user of microprocessors is the aircraft companies, who use microprocessors, mini- and micro-computers in their instrumentation and control systems.

3.2.2 Adoption Rates by Organizational Status

Table 3.3 shows adoption rates for each of the eight technologies under study according to the affiliation of the plants; whether they are part of a multi-plant firm (MPF) or a single-plant entity (SPF). A striking pattern emerges, which is both consistent for all the technologies and statistically significant in each case. Plants which are affiliated to multi-plant corporations have much higher rates of adoption than single-plant firms. For numerically controlled machines, the use of computers in design and manufacturing,

Table 3.3 ADOPTION RATES BY ORGAN STATUS

	SPF	MPF	χ^2	PROB
NC	25	56	58.8	.0001 SIG
CNC	31	51	26.0	.0001 SIG
COMPUTER FOR COMMERCIAL	54	78	37.3	.0001 SIG
COMP FOR DESIGN	11	34	39.4	.0001 SIG
COMP FOR MFG	29	57	44.2	.0001 SIG
PROG HANDLING	2	11	23.6	.0001 SIG
NON-PROG HANDLING	39	51	9.9	.002 SIG
MICRO PROC IN PRODUCT	19	33	15.4	.0001 SIG
TOTAL # OF RESPONDENTS	322	306		

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and for programmable handling systems, adoption rates among multi-plant companies are double what they are for single-plant companies. This may not be surprising when one considers the financial resources available to multi-plant firms, as suggested by the economies of scale implicit in such industrial enterprises.

This does show that multi-plant companies are more innovative in their introduction of new process technology than single-plant companies. Though data on company size (as measured by total sales or assets) were not obtained directly in this survey, multi-plant companies are inevitably larger than single-plant firms. From Table 3.3, therefore, it can be inferred that larger multi-plant enterprises are more likely to adopt the latest available process innovations than are smaller single-plant companies. It should be recalled, however, that small firms tend to specialize in product rather than process innovations (Utterback 1979).

These findings do, however, run contrary to the popularized notions that small, single-plant companies are relatively more innovative than their larger counterparts for all kinds of technologies, and point out the importance of distinguishing between product and process innovations. In sorting out the myths from the realities of small business innovation generation, therefore, it is worth considering the cautionary words of a recent Brookings study:

> Among the common, if not universal, beliefs is that the small business sector is a powerful force for technological innovations...the difficulty with these beliefs is that they are based on a very limited amount of knowledge about the dynamics of small-business activities, as well as incomplete data (Armington and Odle 1982, 14).

3.2.3 Adoption Rates by Size of Plant

Though data were not collected on corporate size, the fact that the study was conducted at the level of the individual plant does allow us to address adoption rate differentials by employment size of plant. Again, a consistent and statistically significant pattern emerges for seven out of the eight technologies. As seen in Table 3.4 larger plants in the survey show consistently higher rates of innovation adoption than smaller plants.

Table 3.4 uses the employment size classification of the Economic Census, and shows consistently higher rates of adoption for all but one of the technologies as one progresses from plants in the 20 to 99 employment size category to plants employing 1000 or more.

The increase in adoption rates for these technologies as one progresses up the plant size scale is highly consistent, ranging from 25 percent adoption of NC in the 20 to 99 employment category to 83 percent adoption for plants employing over 1000. The only exception to this progression is the use of non-programmable handling systems. Higher adoption rates among smaller plants in this case is understandable when one considers that this type of technology can include simple, manual material handling systems (fork lifts, etc.) which are cheaper to use in small plants.

3.2.4 Adoption Rates by Age of Plant

The results in Table 3.5 show the least expected and perhaps the most provocative findings to come out of this study. *A priori* we expected to find newer plants to be more innovative in their use of new technologies than older plants. Our findings, however, show the reverse to be the case, and this pattern is both consistent and statistically significant for six of the eight technologies. On the whole, older plants are more innovative users of new process technologies than the newer ones. For NC and CNC machine control systems, and for the use of

Table 3.4 ADOPTION RATES BY SIZE OF PLANT (EMPL.)

	1-19	20-99	100-249	250-999	1000 & MORE	χ^2	SIG
NC	10	25	43	67	83	107.4	.0001 SIG
CNC	8	23	50	69	78	121.2	.0001 SIG
COMPUTER FOR COMMERCIAL	24	50	77	91	95	114.7	.0001 SIG
COMP FOR DESIGN	3	9	21	41	80	125	.0001 SIG
COMP FOR MFG	8	21	53	74	90	153.5	.0001 SIG
PROG HANDLING	0	1	2	15	35	88.1	.0001 SIG
NON-PROG HANDLING	48	43	39	51	60	8.2	.083
MICRO PROC IN PRODUCT	5	19	32	36	40	29.2	.0001 SIG
TOTAL # OF RESPONSES	40	279	135	125	40		

computers in commercial, design and manufacturing activities, manufacturing plants built prior to 1939 show higher adoption rates than do plants built after 1940. Indeed, when age of plant is compared by decade, a progressive inverse relationship exists between the age of plants and their propensity to adopt new technologies.

These results therefore show conclusive evidence that in a key part of the durable goods sector older manufacturing plants across the country have been rejuvenating themselves to remain competitive. Much of this retooling can be explained by the fact that most of the new technologies are discrete units that can be introduced into a plant in an incremental fashion. For example, a CNC system can be introduced into an existing plant for metal cutting or metal forming without a massive reorganization of total plant layout. This is particularly true of computers used in commercial or design activities. The results clearly imply that older plants in the United States cannot be written off as users of out-dated technology. The results are also testimony to the inherent potential that older plants may have for increasing their technological sophistication.

One other explanation for the patterns evident in Table 3.5 lies in the consolidation or rationalization procedures that may have been experienced by some of the multi-plant companies surveyed. During times of recession or organizational restructuring it is possible that one or two plants within a multi-locational system may have been closed and the best available technology consolidated in an older plant. Yet this trend would have had to be a major one among most of the 628 respondents to account for the consistent patterns seen in Table 3.5.

The only exceptions to the patterns seen in Table 3.5 are for non-programmable handling systems and the use of microprocessors in final products, where

Table 3.5 ADOPTION RATES BY AGE OF PLANT

	1939 OR BEFORE	1940 - 49	1950 - 59	1960 - 69	1970 - 81	χ^2	SIG
NC	59	52	41	33	28	32.7	.0001 SIG
CNC	57	46	45	37	27	26.0	.0001 SIG
COMPUTER FOR COMMERCIAL	79	70	67	62	58	13.3	.009 SIG
COMP FOR DESIGN	41	30	23	18	14	26.3	.0001 SIG
COMP FOR MFG	58	57	45	40	30	23.5	.0001 SIG
PROG HANDLING	9	16	6	5	2	16.3	.003 SIG
NON-PROG HANDLING	34	49	49	48	46	6.7	.150
MICRO PROC IN PRODUCT	31	28	21	28	19	6.2	.183
TOTAL # OF RESPONDENTS	111	63	109	181	150		

no statistically significant differences in adoption rates are seen by age of plant. Adoption rates for manual and non-programmable handling systems do not vary much by age of plant for the same reasons that they do not vary by size of plant, i.e. such systems are used by most plants. As for the use of microprocessors in final products, older plants are relatively more innovative users than are the newer plants, but not to a statistically significant degree. The exception here lies in higher adoption rates (28 percent) for plants built in the 1960s, when microprocessors in American industry went through a major growth period.

The results of Table 3.5 do however point to the importance of differentiating between age of plant and age of capital stock when assessing the technological sophistication of American industry. Indeed, the potential among older plants for using the best available or practical process technologies can be directly related to the product cycle argument for regional industrial change developed elsewhere (Rees 1980; Erickson and Leinbach 1979). Since most newer plants are likely to be branch plants, the product cycle argument suggests that branch plants produce more mature products using standardized process technology. The standardization of production implies a lesser need to introduce more flexible processes like CNC, whose adaptability is better suited to the early types of product development in older plants.

3.2.5 Adoption Rates by Research and Development Intensity

Table 3.6 examines variations in adoption rates according to whether research and development (R & D) activity is conducted in the manufacturing plants surveyed. This allows us to test whether or not the more R and D intensive plants are more likely to use new technologies. From Table 3.6 we see that 505 plants, or 80 percent of the total, performed some form of R and D activity

Table 3.6 ADOPTION RATES BY R + D INTENSITY

	NO R + D	R + D AT OTHER LOCATION	R + D ON SITE	χ^2	SIG
NC	34	54	40	4.1	.127
CNC	37	54	41	3.2	.198
COMPUTER FOR COMMERCIAL	44	59	70	21.3	.0001 SIG
COMP FOR DESIGN	14	23	24	4.1	.130
COMP FOR MFG	23	59	46	16.4	.0003 SIG
PROG HANDLING	4.6	14	6	3.8	.153
NON-PROG HANDLING	45	50	45	.4	.818
MICRO PROC IN PRODUCT	15	12	28	9.8	.008 SIG
TOTAL # OF RESPONDENTS	87	36	505		

on site, while only 87 plants or 14 percent of the total had no R and D activity on site. Largely because of the high proportion of plants with R and D on site no statistically significant differences in adoption rates were found for five out of the eight technologies relative to the presence or absence of R and D.

For users of computers in commercial activities 70 percent conducted R and D at the same location, i.e. they were more R and D intensive. For users of computers in the manufacturing process per se, 59 percent conducted R and D at a separate location within the firm. Significant differences in adoption rates also emerge for users of microprocessors in their final products. This last pattern does show that the more innovative users of microprocessors in their final products had a substantial amount of R and D on site, a pattern that might be expected from the creative nature of such endeavors when much on-site work would have been needed to apply the microprocessors to existing or new products.

For five of the eight techniques, plants with R and D activities located at some other site within the corporate system showed the highest adoption rates. Because of the large number of respondents with R and D on site, adoption rates were also examined according to the number of R and D workers as a proportion of total employment at each plant. A table of results is not included here because the trends seen are very similar to those in Table 3.6. Only 75 plants (12 percent of total respondents) had R and D workers that amounted to 5 percent or more of total employment at that plant, while only 21 plants reported over 10 percent of their workers as R and D personnel.

3.2.6 Adoption Rates by Region

One of the major goals of this project was to examine differences in innovation adoption by geographical region, based on the hypothesis that plants in various parts of the country might show variations in their propensity to adopt the latest technology. Table 3.7 shows variations in adoption rates by Census region, based on a random response pattern. Though statistically significant differences in adoption rates only appear for two of the eight technologies, there are some important regional differences in the adoption rates for the various innovations.

Regional differences in the adoption of CNC are statistically significant, with the North Central region showing an adoption rate of 47 percent, followed by the Northeast, the West and the South. The high adoption rate for CNC in the North Central region may be expected from the region's industrial base which includes the largest industrial states of the Manufacturing Belt (Michigan, Ohio, Illinois) and the area's role as the historic center for the machine tools industry (Rosenberg 1972). The North Central region also has the highest adoption rate for NC, where (as might be expected) the adoption pattern by region is similar to that for CNC. The North Central region also shows the highest adoption rate for the use of computers for commercial activities.

In the case of computers for commercial activities however, regional variations in adoption rates are very small. Since the use of computers for commercial purposes did not show statistically significant differences by sector (Table 3.2), it is not surprising that major regional differences do not show up. Plants in all four regions of the U.S. show adoption rates above 60 percent for the use of computers in commercial activites. It is perhaps

Table 3.7 ADOPTION RATES BY CENSUS REGION

	NE	NC	S	W	χ^2	PROB
NC	39	45	32	35	7.68	.053
CNC	41	47	28	37	12.4	.006 SIG
COMPUTER FOR COMMERCIAL	62	69	63	62	2.7	.441
COMP FOR DESIGN	23	22	23	25	.2	.977
COMP FOR MFG	47	46	38	36	3.9	.272
PROG HANDLING	6	7	4	11	3.9	.267
NON-PROG HANDLING	40	42	55	51	8.4	.038 SIG
MIC PROC IN PRODUCT	31	26	20	23	4.3	.226
TOTAL # OF RESPONDENTS	114	325	128	61		
AVERAGE RANK (EXCL NON-PROG HANDLING)	2	1.9	3.3	2.6		

more surprising that regional differences in the use of computers for design purposes, as well as for manufacturing, are not larger.

Adoption rates for programmable (mostly robotic) handling systems are low by region as they are by sector. Regional variations in the use of non-programmable handling systems on the other hand are distinct and statistically significant. In this case it is the Southern region which shows the highest user rate and the Northeastern states the lowest rate. The high adoption rate in the South is testimony to the continued dominance of the region by branch plants (Hansen 1980), despite the rapid growth of certain growth centers in the Sun Belt states (Rees 1979). Regional differences in the use of microprocessors in final products are not statistically significant. The dominance of the Northeast in this case is testimony in part to the development of mini- and micro-computers in areas such as Boston (Dorfman 1982).

Given the size and diversity of the United States it may not be surprising that a complex pattern of regional differences in the adoption of new technologies is forthcoming in Table 3.7. When an average ranking of regional adoption rates is carried out for seven of the eight technologies (non-programmable handling systems are left out because of their lower technology base), the dominance of the Manufacturing Belt as an user of the latest available process technology does stand out. The North Central region ranks highest, followed by the Northeast, the West and the South. Though such rankings should not be overemphasized, it does point out that despite the relative growth of the South and West in the last 15 years, this does not imply that industries in the growth regions are more prominent users of the latest available technology. Indeed, as suggested by the age of plant variable in Table 3.5 it is the older industrial regions of the North Central and Northeastern parts of the Manufacturing Belt that display the highest propensity to use new production technology. Thus, the innovative capacity of the older industrial heartland should not be overlooked in any attempt at reindustrialization or economic recovery that may be initiated at the federal or state level.

3.2.7 Adoption Rates by Metropolitan Location of Plants

Table 3.8 shows adoption rates according to the metropolitan character of the counties in which respondents are located. The four-fold division of counties in Table 3.8 includes:

- large metro implying counties within SMSAs of over 1 million people
- small metro defined as counties within SMSAs of less than 1 million
- urban implying nonmetropolitan counties that include at least one city with over 10,000 population
- and rural including nonmetropolitan counties with no city over 10,000 people.

Table 3.8 shows statistically significant differences in adoption patterns for only two of the eight technologies: numerical control, and the use of microprocessors in the final product. The adoption rate for NC is highest for plants in the smaller SMSAs, not the largest, while the lowest adoption rates occur in the rural areas. This same pattern is also true for plants using microprocessors in their final products. Indeed, adoption rates in the largest urban agglomerations are highest for only five of the eight technologies, and they are only marginally higher for two of these: CNC, and non-programmable handling systems. This therefore suggests that the largest urban areas are not necessarily the most conducive environments for companies that use the latest available technologies. The adoption rates seen in Table 3.8 do suggest that smaller SMSAs and to a large extent, the more urbanized of the nonmetropolitan counties are also conducive environments for the adoption

Table 3.8 ADOPTION RATES BY METROPOLITAN LOCATION

	LARGE METRO	SMALL METRO	URBAN	RURAL	χ^2	PROB
NC	43	46	36	30	8.7	.03 SIG
CNC	43	42	41	33	3.06	.383
COMPUTER FOR COMMERCIAL	62	66	74	62	6.07	.108
COMP. FOR DESIGN	26	20	25	19	2.4	.492
COMP FOR MFG	46	39	49	40	3.95	.267
PROG HANDLING	7	6	7	4	1.18	.759
NON-PROG HANDLING	44	43	48	46	.879	.831
MICRO PROC IN PRODUCT	28	33	17	18	12.2	.007 SIG
TOTAL # OF RESPONDENTS	218	175	140	95		
AVERAGE RANK (EXC NON-PROG HANDLING)	1.7	2.3	2.1	3.6		

of these new production techniques. For three of the eight technologies (computers for commercial and manufacturing activities, and non-programmable handling systems) the more urbanized nonmetro counties show the highest adoption rates. Though the larger SMSAs still show the highest average ranking for all technologies bar non-programmable handling, the more urbanized nonmetro areas show the second highest ranking, followed by the smaller SMSAs and then the more rural areas.

3.2.8 Further Analysis of Regional and Metropolitan Adoption Patterns

Thus far, statistically significant differences in the adoption patterns of new production technology were evident by industry type, organizational status of plants, size and age of establishments, and their R and D intensity. Regional and metropolitan differences in adoption rates did not come out to be statistically significant in most cases, though clear differences in the proportion of adopters are reflected in tables 3.7 and 3.8.

Despite the lack of statistically significant differences in adoption patterns by region and metropolitan type at this level of analysis, it is still important to inquire whether differences in adoption rates do come out at a more disaggregated level of analysis when differences in industry size, organization status, R and D intensity, age and size of plants are examined between regions and between different types of metropolitan areas. Some significant differences do indeed come out at this level of analysis, as shown in tables 3.9 through 3.13.

Since the industrial structure of a particular locality can have a major influence on the adoption of new technologies, this was controlled for in the research design when the target sectors were sampled geographically in proportion to their share of the total number of plants in the various SIC codes.

Nevertheless adoption rates in any of the six target industries (Table 3.2) could be significantly different in one region compared to another. Such differences were examined at both the 3 and 4 digit SIC level for all the target sectors but results were not statistically significant.

One methodological problem with analysis at this disaggregated scale involves the use of chi-square tests for showing statistical association between cells where expected counts are less than five. Because of this, results presented here are limited to a set of dichotomous variables that show statistically significant results.

(i) The Influence of Organizational Status

When regional adoption rates are examined by organizational status (Table 3.9) statistically significant differences are evident between regions for single-plant firms adopting three key technologies: NC, CNC and microprocessors in the final product. These findings are important in that they show small, single-plant firms in the industrial heartland (the Northeast and North Central regions) to have far greater adoption rates for NC and CNC than similar firms in the Southern and Western Census regions. Likewise the use of microprocessors in final products is more prevalent in single-plant firms in the Northeast and Western regions than in the Midwest or South. It is no coincidence that in the case of CNC, most of the early development work was spawned in the Manufacturing Belt, whereas in the case of microprocessors in products, Massachusetts and California firms appear to have been the most progressive in the development of mini- and micro-computers. For single-plant firms therefore, this suggests a distance-decay or contagious spread effect in adoption patterns where adoption rates are lower in regions furthest removed from the spawning-grounds of these leading-edge technologies. Because of the

Table 3.9 REGIONAL ADOPTION RATES BY ORGANIZATIONAL STATUS

		NE	NC	S	W	PROB
NC	SPF	27	31	11	17	.02*
	MPF	55	60	49	53	.47
CNC	SPF	37	37	16	13	.004*
	MPF	47	56	38	60	.06
COMPUTER FOR COMMERCIAL	SPF	54	58	47	43	.36
	MPF	70	80	76	80	.52
COMP FOR DESIGN	SPF	17	9	10	15	.49
	MPF	31	36	32	34	.93
COMP FOR MFG	SPF	38	32	20	15	.07
	MPF	57	60	52	55	.76
PROG HANDLING	SPF	3	2	0	3	.37**
	MPF	10	12	7	19	.35
NON-PROG HANDLING	SPF	37	35	47	47	.30
	MPF	43	49	61	55	.22
MICROPROC IN PRODUCT	SPF	33	16	11	20	.01*
	MPF	29	38	27	27	.33

*Statistically significant (using chi square).
**More than 20 percent of cells have expected counts less than 5.

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comparative advantage that multi-plant firms have in spreading new production technologies in a variety of locations within their corporate system, it is not surprising that multi-plant firms in Table 3.9 show much less regional variations in adoption rates for all the technologies studied.

The distance-decay effect for single-plant firms does not appear as statistically significant however when metropolitan and nonmetropolitan adoption rates are compared in Table 3.10. Adoption rates for NC and microprocessors are higher for plants in metropolitan areas than in nonmetropolitan counties. Table 3.10 also shows adoption rates for NC and microprocessors to be significantly higher in metropolitan areas for multi-plant firms, showing that these key technologies are more likely to be introduced in urban rather than rural plants of multi-locational firms. Presumably the more sophisticated labor force associated with urban rather than rural locations would be a major factor in the introduction of these relatively complex technologies.

(ii) The Influence of Plant Size

Table 3.11 shows regional adoption rates by size of plants, using employment levels below 100 to define smaller plants and employment levels of 100 or more to define larger plants. Regional adoption rates are not significantly different for any of the techniques except CNC among the smaller plants. For smaller plants using CNC however, adoption rates in the industrial heartland (the Northeast and North Central regions) are significantly higher than in the South and West. This suggests that the argument made earlier regarding single-plant firms also pertains to smaller plants. Regional differences in the adoption rate of small plants are also evident for NC and microprocessors, but are not statistically significant.

Table 3.10 METROPOLITAN ADOPTION RATES BY ORGANIZATIONAL STATUS

		LARGE METRO	SMALL METRO	URBAN	RURAL	PROB
NC	SPF	27	29	22	19	.56
	MPF	62	62	49	40	.03*
CNC	SPF	32	32	36	19	.27
	MPF	56	52	46	47	.58
COMPUTER FOR COMMERCIAL	SPF	51	53	65	45	.15
	MPF	74	79	83	77	.56
COMP FOR DESIGN	SPF	12	9	13	12	.83
	MPF	39	31	36	26	.47
COMP FOR MFG	SPF	32	27	36	17	.17
	MPF	59	49	62	62	.39
PROG HANDLING	SPF	1	4	3	0	.36**
	MPF	15	9	12	9	.54
NON-PROG HANDLING	SPF	38	39	40	40	.99
	MPF	51	48	56	53	.77
MICROPROC IN PRODUCT	SPF	17	29	12	15	.04*
	MPF	41	36	23	22	.04*

*Statistically significant (using chi square test).
**More than 20 percent of cells have expected counts less than 5.

Table 3.11 REGIONAL ADOPTION RATES BY EMPL. SIZE OF PLANT

		NE	NC	S	W	PROB.
NC	1-99	27	25	16	19	.43
	≥100	54	63	50	54	.27
CNC	1-99	29	24	9	16	.02
	≥100	56	67	52	62	.16
COMPUTER FOR COMMERICAL	1-99	46	48	46	39	.83
	≥100	79	87	85	89	.59
COMP FOR DESIGN	1-99	13	7	7	10	.57
	≥100	37	35	43	46	.66
COMP FOR MFG	1-99	24	21	16	7	.25
	≥100	69	68	65	68	.97
PROG HANDLING	1-99	2	1	0	3	.59
	≥100	11	12	9	19	.65
NON-PROG HANDLING	1-99	40	40	54	47	.21
	≥100	39	44	55	59	.16
MICROPROC IN PRODUCT	1-99	21	17	10	23	.30
	≥100	42	35	31	26	.48

(iii) Differences Due to Age of Plant

Because of the significant trends portrayed by the age of plant variable at the national level (Table 3.5) regional and metropolitan differences in this variable are further explored in tables 3.12 and 3.13. Here a dichotomous variable is used to define older plants as those established before 1960 and newer plants as those founded in 1960 or later. From Table 3.12 significant regional differences in adoption rates are evident for older plants using NC and CNC. Again, the role of the Northeastern and Midwestern states as the wellspring of machine tools technology comes out, with adoption rates among pre-1960 plants being much higher in the North Central region than in the South. Regional differences in the adoption of these technologies do not appear as statistically significant for plants set up after 1960, reflecting the spread of those production innovations into other regions.

User rates for non-programmable handling equipment also reveal statistically significant regional differences for older plants, showing the plants of the South and West to be the most frequent users. This reflects the more traditional handling systems that one may expect among the branch plants of peripheral regions in the South and West.

When adoption rates for older and newer plants are examined by their urban and rural locations (Table 3.13), the only statistically significant differences appear for newer plants introducing two innovations: numerical control, and microprocessors in product. Again these newer technologies are more likely to be introduced in the more sophisticated labor markets of metropolitan areas rather than nonmetropolitan locations. Unexpectedly in these cases, the same pattern does not hold for the older plants.

Table 3.12 REGIONAL ADOPTION RATES BY AGE OF PLANT

		NE	NC	S	W	PROB
NC	pre 1960	40	60	36	41	.005
	1960 or later	39	29	29	29	.51
CNC	pre 1960	43	60	29	41	.001
	1960 or later	39	32	28	35	.52
COMPUTER FOR COMMERCIAL	pre 1960	71	77	67	54	.08
	1960 or later	53	61	61	66	.65
COMP FOR DESIGN	pre 1960	26	32	36	30	.84
	1960 or later	20	13	16	23	.40
COMP FOR MFG	pre 1960	56	58	42	33	.08
	1960 or later	38	34	36	37	.95
PROG HANDLING	pre 1960	7	11	5	15	.48
	1960 or later	5	3	4	6	.66
NON-PROG HANDLING	pre 1960	37	39	57	59	.04
	1960 or later	42	46	53	44	.58
MICROPROC IN PRODUCT	pre 1960	27	29	23	12	.26
	1960 or later	33	22	18	31	.17

Table 3.13 METROPOLITAN ADOPTION RATES BY AGE OF PLANT

		LARGE METRO	SMALL METRO	URBAN	RURAL	PROB.
NC	pre 1960	51	51	55	37	.99
	post 1960	35	40	16	27	.009*
CNC	pre 1960	51	50	48	50	.99
	post 1960	35	34	32	25	.59
COMPUTER FOR COMMERCIAL	pre 1960	66	72	76	85	.24
	post 1960	57	59	71	53	.17
COMP FOR DESIGN	pre 1960	35	26	38	19	.25
	post 1960	17	14	13	19	.75
COMP FOR MFG	pre 1960	56	44	60	48	.24
	post 1960	35	33	38	37	.94
PROG HANDLING	pre 1960	14	6	10	3	.21
	post 1960	1	6	4	5	.28**
NON-PROG HANDLING	pre 1960	46	42	45	33	.67
	post 1960	42	45	51	53	.48
MICROPROC IN PRODUCT	pre 1960	30	27	20	28	.59
	post 1960	26	36	15	15	.007*

*Statistically significant (using chi square).
** More than 20 percent of cells have expected counts less than 5.

3.2.9 Adoption Patterns over Time

In this survey we were also able to identify the spread of new technologies over time. The cumulative number of adopters over time are shown for six innovations in figures 3.1 and 3.2. The most striking pattern to be seen is the surge in the adoption of these new technologies in the 1960s and the 1970s. In Figure 3.1 the adoption of numerical control shows a relatively smooth growth curve, but not as steep as for its successor: computerized numerical control. Programmable or robotic handling systems are still in their infancy in terms of development as reflected in the relatively low number of total adopters. The steep slope to the adoption curve is even more pronounced throughout the 1960s and 1970s in Figure 3.2. The use of computers in commercial (non-manufacturing) activities had spread relatively rapidly throughout the plants surveyed by 1982, more so than the use of computers (excluding CNC) in manufacturing and the use of microprocessors in final products.

These diffusion curves do not appear to reflect the influence of the business cycle and the deep recessions of the mid-1970s and early 1980s. Despite the relative economic stagnation of the 1970s, the introduction of significant innovations seems to be the result of long term strategic planning decisions on the part of industrialists, and these long term considerations seem to override short term cyclical tendencies. The rapid diffusion patterns revealed in figures 3.1 and 3.2 also indicate that the pace of technological change seemed to be accelerating during the turbulent decade of the 1970s, at least in key parts of America's machinery industries.

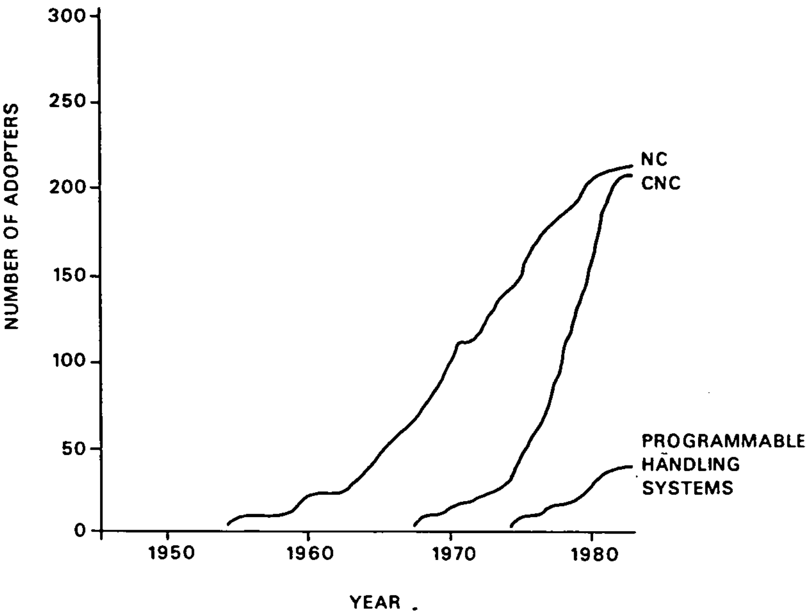

FIG. 3.1

Cumulative Adoption Patterns Over Time

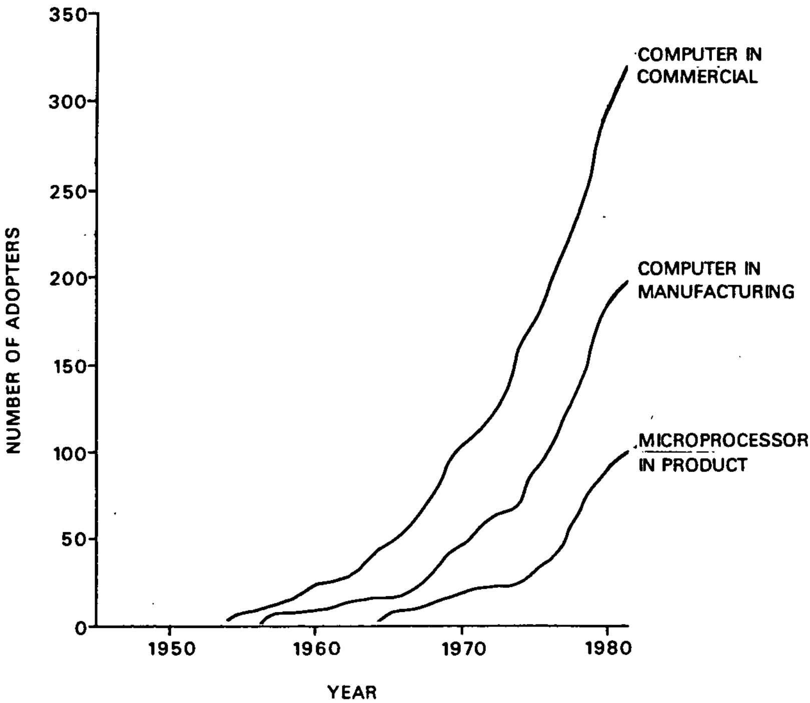
350
300
250
200
150
100
50
0
NUMBER OF ADOPTERS
1950
1960
1970
1980
YEAR
COMPUTER IN COMMERCIAL
COMPUTER IN MANUFACTURING
MICROPROCESSOR IN PRODUCT

Figure 3.2

3.3 Summary

From this study of the spread of automated production technology in the American machinery industry we have seen that adoption rates do vary significantly by type of industry, by type of company, by size and age of plant and by the presence or absence of R and D. Our findings that older plants are more likely users of these new production technologies than newer plants is testimony to the continuous retooling process on-going in the more established industrial areas of the country. This rejuvenation process has been glossed over by many studies of American industrial change in recent times.

At its simplest, the above study gives evidence that market mechanisms are working in the sense that such retooling is mandatory for firms to remain competitive. The relatively rapid adoption of new technology in the 1970s reflected the long term nature of the innovation investment decision that did not seem affected by downturns in the business cycle during the period.

Since these adoption patterns also reveal regional differences (though not to a statistically significant degree), the study suggests a matching of capital with labor by region, i.e., the more advanced production technologies are being introduced in the higher skill, higher wage areas of the industrial Midwest while less of these technologies or less advanced versions are being introduced to a lesser degree in the lower wage, lower skill labor markets of the South and West. Indeed this alignment process can be seen to follow a product cycle interpretation of regional industrial change proposed earlier for the United States (Rees 1980). The greater use of CNC in the industrial Midwest suggests at least for the machinery industry, that early development work is still on-going in that region, while more standardized production is still typical of peripheral regions in the South and West.

Other findings with policy implications are seen at the regional scale where small single-plant firms show significant differences in their propensity to adopt leading-edge technologies. Single-plant firms show far higher adoption rates for computerized machine control equipment in the industrial Midwest, the spawning-ground for the initial development of this technology. Likewise, the use of microprocessors in final products is more prevalent in their region of origin: in this case the Northeast (notably Massachusetts) and the West (notably California). This suggests a contagious diffusion or distance-decay effect within regions that spawn leading-edge technologies, and is testimony to the propulsive nature of innovative regions. Though (as might be expected) multi-plant firms show much less regional variation in the adoption of the technologies under study, they are clearly more prevalent users of key technologies (computerized machine control and microprocessors) in metropolitan rather than nonmetropolitan environments. This again reflects the product cycle argument at the metropolitan scale (Erickson and Leinbach 1979). For policy-makers interested in the nurturing of small business in particular this study shows that small firms nearer to the source of innovation are more likely to use leading-edge technologies. Hence some attention may need to be given to encouraging the spread of these technologies to less innovating environments where multi-plant firms have a clear advantage over single-plant firms who suffer more from the tyranny of distance.

4. The Adoption and Labor Impact of Machine Control Systems Among Small Plants

4.1 Research Design

The second project discussed in this study*, while building on the research design reported in part 3, differs from the preceding project in two principal ways. First, the advanced production technology being traced includes only two types of machine control systems--numerical control (NC) and computerized numerical control (CNC). From a technology life-cycle perspective, the succession from conventional machine control (which depends on the manual skills and eye-hand coordination of an operator) to NC, automated machine control (CNC) and computer-assisted manufacturing (CAM) is what is explored here. This study is thus more targeted than the previous one in the sense that it deals only with one set of key production technologies. These two process technologies are traced as they diffuse through plants and shops which already have at least minimal machine control capabilities and have 250 or fewer employees. It was estimated that as of October, 1982, there were approximately 38,600 plants and shops with fewer than 250 employees in the U.S.; accounting for 85 or 90 percent of all plants in the metalworking industry.** The exclusion of larger plants from the study design does place some limits on conclusions concerning the productivity of metalworking as an industrial sector since larger plants account for a disproportionately greater

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*This part of the report draws upon a study by Donald Hicks, Technology Succession and Industrial Renewal in the U.S. Metalworking Industry, Discussion Paper, University of Texas at Dallas, and funded by the University Computing Company, Dallas, Texas.

**These estimates are the most up-to-date available and were provided by the research staff of the American Machinist (New York, N.Y.). According to estimates taken from County Business Patterns (1980) there were 135,961 establishments within SIC codes 25, 33 to 39, of which 94 percent employed fewer than 250 employees.

portion of sector productivity as measured by value-added or total shipments. Nevertheless, a different perspective on the industry was sought in this study. Special attention was focused on the variations across thousands of small plants and shops as providers of employment, as labor environments for workers, and as settings for the redefinition of work, as well as for the industrial adjustments involving technology upgrading in pursuit of productivity enhancement.

Industry records indicated that 12,523 plants and shops were known to have at least minimal NC/CNC capabilities; of these 7,994 (64 percent) employed 250 or fewer employees. This stratum served as both the sampling frame and the effective sample for this study. A mailed questionnaire was sent to each of the 7,994 plants and shops between November 15-21, 1982. Of the surveys returned completed, the data from 1,172 usable questionnaires (adjusted response rate of 15 percent) were coded into 73 discrete variables.

4.2 Background: Small Plants in the Metalworking Industry and their Labor Context

A number of background characteristics defining the industry at-large are identified here, to provide further context for this part of the report. Here the metalworking industry is composed of appropriate 3 and 4 digit SIC sectors within the following broadly defined industries:

SIC	Business and Industry
25	Furniture and Fixtures
33	Primary Metal Industries
34	Fabricated Metal Products
35	Machinery, Except Electrical
36	Electric and Electronic Equipment
37	Transportation Equipment
38	Instruments and Related Products
39	Miscellaneous Manufacturing Industries

The greatest concentrations of plants are in the East North Central (32 percent) and Middle Atlantic (20 percent) regions. At the state level, New York, Pennsylvania, Ohio, Illinois and Michigan in the East and Midwest and California in the Far West are the locations of distinct concentrations of plants within the industry. The economic geography defined by these plants as suggested in Section 2 illustrates the historical concentration of growth in these industries. Since the medium for this industry is metal, the concentration which defines the industry continues to be reinforced by the low value-to-weight ratios that characterize metal product markets and the relatively high transportation costs which are registered as competitive disadvantages as supplier-producer linkages become extended.

While the oldest plant in the survey began operation in 1813, only 2 percent of the plants date back to the 19th century. Of those plants in operation in late 1982, the vast majority are of post-Depression vintage with only 13 percent having begun operation before 1940. Since 1940, the cohort sizes of new plants had been increasing until a slight reversal was experienced in the mid-1970s. Forty percent of the plants commenced operation between 1960 and 1973.

Not only was there a growth boom in the opening of small metalworking plants in the 1960s and early 1970s, but as Figure 4.1 shows, there occurred a rapid rate of adoption of CNC among these plants in the 1970s. Indeed the high rate of adoption of CNC seen in Figure 4.1 is similar to the patterns described earlier in Section 3.2.9. What we see here is an accelerating pace of technological change even among small plants in the 1970s, further testimony to the long term nature of the innovation adoption decision.

4.2.1 The Labor Union Context and State Right-to-Work Provisions

Since the focus of this part of the study is on reasons why new machine control systems were adopted and the labor impact of these techniques, the unionization and right-to-work context of the industry under study are important to consider.

Unions have commonly been identified as impediments to the flexibility needed by plants as they attempt to adjust to shifting market conditions. From this perspective, unions are viewed as institutions that often tend both to preserve increasingly outmoded and inappropriate exchange relationships among capital, the state and labor and to slow the pace of industrial adjustment. From another perspective, however, unions are viewed as instruments to consolidate gains in working conditions and quality of life on and beyond the job...ensurers of job security in a whipsaw and exploitative capitalist economy. While this issue is far too complex to be addressed definitively by a single data set, the present study does yield findings that are relevant to this longstanding clash of perspectives.

The union status of production workers can be expected to influence patterns of employment change in a wide variety of industrial sectors and settings. To the extent that union status is tied to wage and benefit packages and formally defined work rules that govern workplace activities, as well as to relatively generous supplemental unemployment benefits for those who are not working, the resulting "social wage" can function to escalate the labor costs facing a plant operation. As a result, cyclical employment contraction may amplify the employment loss due to structural changes that may be sweeping through an industry. Further, these more chronic pressures may be largely independent of the employment contraction that may either prompt or result from the adoption of productivity-enhancing technology. The causal orderings which lace these factors together have long been the subject of heated debate.

The role of unions in the employment change and technology upgrading taking place throughout the metalworking industry must be qualified by the fact that unions are present in relatively few plants. In fewer than one in four (23 percent) plants in this study are the production workers unionized. Examination of the regional distribution of unionization reveals that unionization rates are the highest in the Middle Atlantic (30 percent) and the East South Central (32 percent) regions and lowest in New England (18 percent) and elsewhere in the South (South Atlantic, 9 percent) and the West (West South Central, 17 percent; Mountain, 11 percent; and Pacific, 15 percent). Generally, there is considerable variation in unionization patterns both within and beyond the Industrial Heartland (cf Table 4.1).

Not only are relatively few plants unionized, but there also has been an historical shift in the industry over time away from the unionization that had existed. Since the 1930s successive cohorts of metalworking plants and shops have been predominantly nonunion (cf Table 4.2). Unionized production settings appear to be in the process of being jettisoned as the plant "mix" of the metalworking industry evolves and slowly filters into new nonunion employment settings within and between regions.

A semicircle of twenty states with legal right-to-work statutes girds the Industrial Heartland and serves as a buffer with the states to the West and Southwest. Since their influence is often thought generally to inhibit the extent of unionization in an area, we might expect to see considerable correlation between the union status of plants in the metalworking industry and the existence of right-to-work provisions across the states in which these plants are located. Unionization rates were discovered to be considerably lower (15 percent) in right-to-work states than elsewhere (24 percent). Indeed, only 3 percent of the plants in this study which are located in right-to-work states have unionized production workers. Even so, the data reported in Table 4.2 indicate that an overwhelming majority of plants in each respective cohort have been located in states which do not have right-to-work statutes. Therefore, it appears that over the past half century, the predominant nonunion orientation of successive birth cohorts of new plants has transformed the metalworking industry far more dramatically than has the more modest interstate flight of new plants into right-to-work havens. Therefore, the bulk of the restructuring of the metalworking industry has occurred in-place.

TABLE 4.1

Union Status of Plants by Region

Region	Union Status of Production Workers					
	Union		Non Union		Total	
	N	%	N	%	N	%
New England	19	17.8%	88	82.2%	107	100.0%
Middle Atlantic	62	30.1	144	69.9	206	100.0
East North Central	101	26.9	274	73.1	375	100.0
West North Central	20	19.8	81	80.2	101	100.0
South Atlantic	6	8.8	62	91.2	68	100.0
East South Central	8	32.0	17	68.0	25	100.0
West South Central	12	17.4	57	82.6	69	100.0
Mountain	4	10.5	34	89.5	38	100.0
Pacific	21	15.4	115	84.6	136	100.0
					1,125	100.0%

30-539 O - 83 - 6

TABLE 4.2

Plant Birth Cohorts by Union and State Right-to-Work Status

Cohort Range	Union N	Union %	Non Union N	Non Union %	Right-to-Work N	Right-to-Work %	Non Right-to-Work N	Non Right-to-Work %
1800 - 1849	1	100.0	-	-	-	-	1	100.0
1850 - 1874	2	66.6	1	33.3	-	-	3	100.0
1875 - 1899	13	72.2	5	27.8	4	22.2	14	77.8
1900 - 1909	14	77.8	4	22.2	1	5.6	17	94.4
1910 - 1919	8	38.1	13	61.9	2	9.5	19	90.5
1920 - 1929	24	55.8	19	44.2	2	4.6	41	95.4
1930 - 1939	16	40.0	24	60.0	3	7.0	40	93.0
1940 - 1949	35	30.7	79	69.3	21	18.0	96	82.0
1950 - 1959	52	25.0	156	75.0	22	10.5	188	89.5
1960 - 1969	58	17.8	267	82.2	57	17.3	272	82.7
1970 - 1979	23	8.0	264	92.0	70	24.0	221	76.0
1980 to Present	-	-	19	100.0	6	28.6	15	71.4
Not Reported	9	25.0	27	75.0	7	12.5	49	87.0
Total	255		878		195		976	

Among plants in this sample, 835 (71 percent) are single-site plants while 80 (7 percent) serve as national headquarters of larger corporate structures and 248 (21 percent) serve as branch plants. While the vast majority of all the plants are nonunion, that general pattern is conditioned by whether a company occupies a single-site plant or is tied into a more complex corporate structure distributed across multiple sites. The influence of corporate structure on union status is able to be traced in Table 4.3. Among single-site plants, 85 percent are nonunion; in contrast, only 60 percent of the plants tied to more complex corporate structures are nonunion. This indicates that it is the growth of independent single-site plants, rather than branching by extended corporate structures, that has had the far greater effect of spurring the growth of nonunion production settings within and beyond the crescent of non right-to-work states. In short, it is the new growth of single-plant firms, rather than corporate branching strategies which is responsible for this smaller plant base of the metalworking industry moving out of the orbit of unionization and into settings offering greater labor control and lower labor costs.

4.3 Results

4.3.1 Factors Influencing Original Adoption of NC/CNC

The decision to adopt advanced production technology can be prompted by many considerations. Respondents were asked to assess the relative importance of several factors that are commonly associated with the decision to integrate new technologies into older production arrangements. Of special importance are those factors that are tied directly to the desired productivity enhancement; also important are those factors which imply a desire to proceed with a labor substitution strategy in cases where appropriately skilled labor is either not

TABLE 4.3

Plant Type by Union Status

		Type of Plant		
		Single-Site Plant	Component of Multiple-Site Company	
Union Status of Production Workers	Union	117 (14.8%)	136 (40.4%)	253 (22.4%)
	NonUnion	675 (85.2%)	201 (59.6%)	876 (77.6%)
		792 (70.2%)	337 (29.8%)	1,129 (100.0%)

available or is available at a prohibitive wage rate under tight labor market conditions that may eventually translate into competitive disadvantage for a company.

In Table 4.4 seven separate factors are rank-ordered according to their prominence as reasons for initially replacing conventional (manual) machine control with an automated alternative such as NC or CNC. The data indicate that the NC/CNC adoption decision is overwhelmingly driven by the desire to increase plant productivity directly. More than seven in ten (71 percent) of the respondents ranked this initial factor either first or second in importance. The second factor in overall importance, and that chosen first by one in five (20 percent) of the plants, is the desire to improve a plant's competitive position within the industry. This overriding concern for productivity enhancement is understandable given the special determinants of competitiveness existing within the metalworking industry as it has developed generally during the past two centuries, and specifically since World War II.

Increasingly, the greater precision and reduced tolerances demanded by sophisticated metal fabrication and assembly production processes have shifted much importance to quality assurance. The desire to improve quality assurance emerged as the third most important factor garnering first or second place rankings among 37 percent of the plants. This factor may be considered indirectly related to improved productivity.

Despite the origins of basic NC technology in the early 1950s as an outgrowth of an early version of military-scientific cooperative R and D, military/defense contract related requirements do not figure prominently in prompting advanced technology adoption. It is interesting to note that while the technological sophistication of production processes is often formally stipulated

TABLE 4.4

Rankings of Factors Prompting NC/CNC Adoption

Reason for NC/CNC Adoption		1st	2nd	3rd	4th	5th	6th or lower	Unranked Factor	NA	Total
Increase productivity	N	518	315	127	38	9	2	96	67	1172
	%	(44.2%)	(26.9%)	(10.8%)	(3.2%)	(0.8%)	(0.2%)	(8.2%)	(5.7%)	(100.0%)
Improve quality assurance	N	133	301	281	118	52	9	81	197	1172
	%	(11.3)	(25.7)	(24.0)	(10.1)	(4.4)	(0.8)	(6.9)	(16.8)	(100.0)
Compensate for shortage of skilled workers	N	74	122	147	133	121	94	54	427	1172
	%	(6.3)	(10.4)	(12.5)	(11.3)	(10.3)	(8.0)	(4.6)	(36.4)	(99.8)*
Improve competitive position within industry	N	236	169	235	118	54	22	85	253	1172
	%	(20.1)	(14.4)	(20.1)	(10.1)	(4.6)	(1.9)	(7.3)	(21.6)	(100.1)
Acquire state-of-the art technology	N	51	35	75	86	136	162	32	595	1172
	%	(4.4)	(3.0)	(6.4)	(7.3)	(11.6)	(13.8)	(2.7)	(50.8)	(100.0)
Required by DOD/NASA contract	N	3	1	10	6	7	169	1	975	1172
	%	(0.3)	(0.1)	(0.9)	(0.5)	(0.6)	(14.4)	(0.1)	(83.2)	(100.1)
Control labor costs	N	52	97	160	143	125	93	52	450	1172
	%	(4.4)	(8.3)	(13.7)	(12.2)	(10.7)	(7.9)	(4.4)	(38.4)	(100.0%)

*Totals do not add to 100.0% due to rounding error.

in contracts let by the Department of Defense and NASA for highly sophisticated parts, the impetus of such an imposed constraint is conspicuous in its absence as a ranked factor. It is importance to recall, however, that this survey does focus on small plants, over 70 percent of which are single-plant firms, while most defense contracts are let to large firms and much production takes place in larger plants. It is only a relatively small number of small firms that either bid or receive such contracts. Finally, the urge to compensate for a shortage of skilled workers or to engage in a strategy of labor substitution in order to adjust to or put downward pressure on total wage costs do not figure prominently in the inventory of motivations to adopt advanced production technologies. One plant in six (17 percent) ranked the desire to compensate for a shortage of skilled workers as either first or second; one plant in eight (13 percent) ranked the desire to control labor costs as either the most important or next most important reason for upgrading its production technology. While these latter two factors rank relatively low in a hierarchy of motivations, where they do occur it is reasonable to suggest that they are judged to be essentially indirect strategies for retaining a competitive position in an increasingly hostile market.

4.3.2 Factors Influencing CNC Programming Expansion Plans

A question was asked concerning the plans of plant managers to upgrade or expand their CNC programming capabilities in the future. The results indicated that a sizable proportion of the plants not only plan to expand their programming capabilities but plan to do so relatively soon. Overall, 76 percent of the plants reported plans to expand their programming capabilities in the future. While the majority of these plants could specify no specific target date for implementing those plans, 15 percent of all plants planned to do so during the first six months of 1983 with another 11 percent planning to do so in the latter half of the year. This means that one in four (26 percent) of the plants planned to proceed with their programmable automation expansion plans and to do so rapidly. Furthermore, these data suggest that the pace of these automation strategies is perhaps being motivated by active and present market considerations along with considerable pent-up demand which is likely the result of the uncertainty characterizing the recent recession.

The expansion plans identified above are generally replicated in Table 4.5 across the nine regions. For all regions, with the exception of the East South Central, more than 70 percent of all plants report plans to expand their programming capabilities. Not only does region not appear to influence plans for process technology upgrading, but there also appears to be little evidence suggesting that plants in the Industrial Heartland, as opposed to those in other regions, are either laggard, recalcitrant or incapable of making the necessary capital adjustments to assure their survival and eventual prosperity.

The corporate structure of the metalworking industry reflected in this sample is such that the bulk of the industry has been seen to be composed predominantly of single-plant firms. For the most part this pattern is replicated across all regions, though the South Atlantic, East and West South Central and West North Central regions which encircle the Industrial Heartland report slightly lower proportions of single-plant firms. In the case of a plant which is part of a multi-plant corporate structure, and especially among "branch" plants which most often serve as regional production centers, there is considerable policy concern that a strategy of subtle disinvestment may be resorted to in order to adjust to building competitive pressures facing the larger corporate entity. Such disinvestment can take many forms including indefinite delay either in the

TABLE 4.5

Plant Plans to Expand NC/CNC Machine Control Capabilities by Region

	Plans to Expand NC/CNC Capabilities				Total	
Region	YES	%	NO	%	N	%
New England	86	(82.7%)	18	(17.3%)	104	(100.0%)
Middle Atlantic	165	(78.2)	46	(21.8)	211	(100.0)
East North Central	298	(78.0)	84	(22.0)	382	(100.0)
West North Central	84	(80.0)	21	(20.0)	105	(100.0)
South Atlantic	54	(80.6)	13	(19.4)	67	(100.0)
East South Central	16	(64.0)	9	(36.0)	25	(100.0)
West South Central	48	(70.6)	20	(29.4)	68	(100.0)
Mountain	27	(73.0)	10	(27.0)	37	(100.0)
Pacific	103	(74.6)	35	(25.4)	138	(100.0)
					1,137	(100.0%)

introduction or state-of-the-art production technology or in the upgrading of already acquired technology. Such delay could indicate a longer-term corporate strategy of gradually downgrading a plant by shifting away from traditional product lines, by surrendering competitive advantages through neglect, or phasing out of an operation in a location that is vulnerable to mounting cost pressures for whatever reasons.

Concern for the increased rate of capital mobility in the service of strategies to disinvest from operations in plants located, for instance, in non right-to-work states, in plants in which production workers are unionized, or in plants located in otherwise high-wage environments has often focused on what is happening among branch plants as an indicator of corporate intentions. As Table 4.6 indicates, whether or not a plant is a single or multi-site operation does not appear to influence plans to upgrade or expand CNC programming capabilities. While 79 percent of the single-site plants report plans to expand their programming capabilities, 74 percent of plants which were part of larger corporate structures likewise planned to do so.

In a similar manner, the age of a plant might also be considered influential in the decision to upgrade production technology. Table 4.7 indicates that relatively high and comparable proportions of plants in all cohorts report plans to expand their programming capabilities. This tendency includes even those plants which date back to the 19th century.

4.3.3 Patterns of Employment Change: 1980-1982

Like other basic manufacturing industries, the sectors that comprise the U.S. metalworking industry have sustained the impacts of both longer-term structural adjustments and shorter-term cyclical adjustments in the regional, national and global marketplaces. The rationalization response to longer-term shifts

TABLE 4.6

Plant Type by Plans to Expand NC/CNC Machine Control Capabilities

		Plant Type		
		Single-Site Plant	Multi-Branch Plant	Total
Plans to Expand NC/CNC Capability	YES	630 (78.7%)	250 (74.2%)	880 (77.3%)
	NO	171 (21.3%)	87 (25.8%)	258 (22.7%)
	Total	801 (70.4%)	337 (29.6%)	1,138 (100.0%)

TABLE 4.7

Expansion of NC/CNC Machine Control by Age of Plant

Plant "Birth" Cohort	Age of Plant	Plans to Expand: YES N	YES %	NO N	NO %	Total N	Total %
1800-1849	133+ yrs.	1	100.0%	-	-	1	100.0%
1850-1974	108 - 132	3	100.0	-	-	3	100.0
1875-1879	83 - 107	16	100.0	-	-	16	100.0
1900-1909	73 - 82	11	61.1	7	38.9	18	100.0
1910-1919	63 - 72	15	75.0	5	25.0	20	100.0
1920-1929	53 - 62	33	78.6	9	21.4	42	100.0
1930-1939	43 - 52	36	83.7	7	16.3	43	100.0
1940-1949	33 - 42	93	80.9	22	19.1	115	100.0
1950-1959	23 - 32	159	76.4	49	23.6	208	100.0
1960-1969	13 - 22	253	78.6	69	21.4	322	100.0
1970-1979	3 - 12	209	72.3	80	27.7	289	100.0
1980 to Present	3	16	76.2	5	23.8	21	100.0
						1,098	(100.0%)

away from old-line manufacturing has translated into a significant dampening of employment growth, and the impact of the recent recession likewise has had a chilling effect on employment. Overall, roughly three out of four plants in this study experienced employment decline during 1980-82.

In 1980, 11 percent of the plants in this study had between one and ten production employees while 8 percent had total employment levels in that range. By 1982, 18 percent of the plants had production employment and 12 percent had total employment levels in that range. As Table 4.8 indicates, across the full range of employment levels, there was noticeable employment contraction during the 1980-82 period. By 1982, larger proportions of the plants had lower production and total employment levels than they did two years earlier. Since the two dates roughly bracket the recent recession, it is likely that both short and long-term economic adjustments are confounded in accounting for this employment contraction.

As Table 4.9 indicates, there is a noticeable regional patterning to this employment contraction. Table 4.9 indicates that the employment contraction was most widespread in the East North Central region where the metalworking industry is the most heavily concentrated and where recessions usually hit the hardest. Diminished demand together with the contagion effect set up by the heavy concentrations of basic manufacturing industries in this region appear to have translated into a softening of the market for the metal products supplier networks. Smaller and fewer orders spread over a fixed number of plants set the stage for significant layoffs.

At the same time, it should be noted that the proportions of plants that experienced employment decline over the 1980-82 period exceeded 70 percent in all subregions save two--the South Atlantic and the East South Central. This

TABLE 4.8

1980 and 1982 Plant Employment

Employment Size	1982 Production N	1982 Production %	1982 Total N	1982 Total %	1980 Production N	1980 Production %	1980 Total N	1980 Total %
None	4	0.3%	-	-	3	0.3%	1	0.1%
1-10	205	17.5	137	11.7%	132	11.3	89	7.6
11-20	209	17.8	168	14.3	189	16.1	142	12.1
21-50	309	26.4	288	24.6	296	25.3	292	24.9
51-100	228	19.5	231	19.7	232	19.8	208	17.7
101-250	104	8.9	202	17.2	150	12.8	230	19.6
250+	35	3.0	85	7.3	48	4.1	105	9.0
No Response	78	6.7	61	5.2	122	10.4	105	9.0
Total	1172	100.1%*	1172	100.0%	1172	100.1%	1172	100.0%

*Totals may not add to 100.0% due to rounding error.

TABLE 4.9

Employment Change 1980-82 By Region

Region	Employment Change (1980-82)					
	Increase		Decrease		Total	
	N	%	N	%	N	%
New England	29	29.3%	70	70.7%	99	100.0%
Middle Atlantic	53	27.9	137	72.1	190	100.0
East North Central	62	18.5	273	81.5	335	100.0
West North Central	27	28.4	68	71.6	95	100.0
South Atlantic	25	39.1	39	60.9	64	100.0
East South Central	8	33.3	16	66.7	24	100.0
West South Central	15	24.1	47	75.8	62	100.0
Mountain	9	27.3	24	72.7	33	100.0
Pacific	29	22.8	98	77.2	127	100.0
					1,029	100.0%

may indicate that not only was the employment contraction spread widely both within and beyond the Industrial Heartland, but the Southern rim locations of some plants appear to have functioned in ways to insulate them from the full impact of the contraction. The fact that the Southeast quadrant of the nation is dominated by states with right-to-work provisions and traditionally strong anti-union sentiment which together translate into a more favorable labor cost environment for business cannot be easily dismissed. However, neither can one overlook the fact that with the diversified growth taking place in these regions, intra-regional competition may have been lower and demand levels correspondingly higher within the industry. Whether or not this might also indicate a conscious channeling of available business by larger corporate entities to these relatively attractive and insulated regions and favorable business climates cannot be determined from this data; however, this possibility cannot be considered inconsistent with these data given the definition of the sample.

Is there any evidence that the recent employment contraction was influenced by the age of plant? In other words, is there any evidence to suggest that relatively newer plants had different rates of employment contraction than did older plants? Table 4.10 presents data relevant to these questions. It does appear that, in general, the older the plant the more vulnerable it was to employment contraction. Especially apparent are the relatively lower proportions of plants started since 1960 which experienced employment declines.

Overall, this would seem to suggest that smaller, older plants offer less efficient production environments than newer plants, assuming that older plants also embody more outdated capital equipment. The findings of Section 3, however, suggest that relationships are not quite that simple, showing older plants across the plant-size spectrum to be more frequent adopters of new technology than newer plants. These findings may indeed suggest that higher rates of

TABLE 4.10

Employment Change (1980-82) By Age of Plant: Chronological Time-Line

Year Plant Began	Age of Plant	Increase		Decrease		Total	
		N	%	N	%	N	%
1800-1849	133+ yrs.	-	-	1	100.0%	1	100.0%
1850-1874	108 - 132	-	-	3	100.0%	3	100.0
1875-1899	83 - 107	1	6.25	15	93.8	16	100.0
1900-1909	73 - 82	2	12.5	14	87.5	16	100.0
1910-1919	63 - 72	2	11.1	16	88.9	18	100.0
1920-1929	53 - 62	2	4.8	40	95.2	42	100.0
1930-1939	43 - 52	7	17.9	32	82.1	39	100.0
1940-1949	33 - 42	18	16.5	91	83.5	109	100.0
1950-1959	23 - 32	38	20.0	152	80.0	190	100.0
1960-1969	13 - 22	94	30.8	211	69.2	305	100.0
1970-1979	3 - 12	81	31.3	178	68.7	259	100.0
1980 to Present	< 3	8	47.1	9	52.9	17	100.0
						1,015	100.0%

innovation adoption and decreased employment levels go hand in hand within smaller, older plants in the metalworking industry as management substitutes capital for labor.

At a time of heightened concern over rapid capital mobility and corporate flight in search of attractive "business climates," the influence of unionization on employment change draws special attention. If the conventional wisdom--and our previous analysis--is any guide, we should not be surprised that unionized plants bore the brunt of the employment loss generated by the recent recession. Table 4.11 offers the evidence. While 86 percent of unionized plants lost production employment between 1980 and 1982, only 72 percent of the nonunion plants did so. The influence of right-to-work status is also reported in Table 4.11. Whereas 76 percent of the plants in states without right-to-work provisions experienced a loss of production jobs, 70 percent of plants in states with right-to-work provisions did so. Therefore, right-to-work status as a characteristic of the labor environment has a relatively modest influence on employment change in comparison to unionization as a feature of the micro-environment to which a plant is anchored.

4.3.4 A Closer Look at Factors Influencing Employment Change

In a series of separate analyses, a sequence of regression models was tested in order to better define the influences on production employment change. Three independent variables-- (1) UNION--whether or not a plant's production workers are unionized; (2) PLANT AGE--the age of plant as a proxy for the vintage of capital stock; and (3) PLANT TYPE--whether a plant is single-site or part of a more elaborate corporate structure were introduced in order to account for the influence each had on change in production employment between 1980 and 1982.

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TABLE 4.11

Employment Change (1980-82) By
Union Status and Right-To-Work State Status of Production Workers

		Union Status of Production Workers			Type of State		
		Union	Nonunion	Total	Right-To-Work State	Non Right-to-Work State	Total
Employment Change (1980-82)	Increase	34 (14.4%)	223 (28.3%)	257 (25.1%)	52 (29.9%)	207 (24.0%)	259 (25.0%)
	Decrease	202 (85.6%)	565 (71.7%)	767 (74.9%)	122 (70.1%)	656 (76.0%)	778 (75.0%)
	Total	236 (100.0%)	788 (100.0%)	1,024 (100.0%)	174 (100.0%)	863 (100.0%)	1,037 (100.0%)

The first model explored the ability of a plant's union status to account for production employment change. The resulting fit of the model to the data yielded the following equation:

$$YP = -8.81 - 13.81\ UNION \qquad R^2 = .02$$
$$(-5.97)(-4.50)$$

Since UNION is a dichotomous variable, the inherent restriction in its capacity to vary limits its ability to account for variation in the dependent variable, YP, which is measured as a continuous variable. The intercept (-8.81) of the resulting regression line represents the average unemployment within the category of plants which were not unionized. This indicates that on average there was a net contraction in employment of 9 percent between 1980 and 1982. If we can assume that there was little layoff-recall turnover activity during that time, then approximately 9 percent of the employees in these nonunionized plants lost their jobs during that time.

The slope of the regression line measures the difference between the average employment change in unionized plants and the average employment change in nonunionized plants. That the impact of the recent recession fell with particular vengeance on union plants can then be clearly inferred. The data indicate that while there was a 9 percent job loss in nonunionized plants during 1980-82, within unionized plants employment contraction was 23 percent. More than one production worker in five employed in unionized plants lost his/her job during the two-year period.

The figures inside the parentheses are the t-values associated with the intercept and slope. Since the values are highly significant, this model serves as evidence of a strong relationship between unionization and employment change.

Yet, we must be cautious in inferring a direct relationship between the two. It is very likely that selected correlates of plant unionization including relatively high wage/benefit packages and strict job definitions through adherence to relatively formalized and restrictive work rules may be mediating a more complex relationship.

High wage/benefit packages and restrictive work rules may in themselves operate to inhibit shifts to more productivity-enhancing technology. Their influence may register on the production and managerial environments in such a way that they translate into competitive disadvantages for firms. In good times the extra burden of these arrangements is borne with far less difficulty than when the economy slows down. At such times of cyclical downturn, and through the course of longer-term structural adjustments rooted in a transforming international economy, unionized production arrangements may complicate industrial adjustments and translate, albeit indirectly, into job losses for these same workers.

In a second model, the variable PLANT AGE was added to the original model. The resulting fitted model was:

$$YP = -3.05 \; -9.39 \text{ UNION } -0.26 \text{ PLANT AGE} \qquad R^2 = .03$$
$$(-14.20) \quad (-2.86) \quad (-3.65)$$

Since the t-values are both significant, this indicates that the relationships between employment change and both union status and age of plant are strong. This serves as evidence that not only did unemployment among production workers cut more deeply into unionized plants, but also job loss was greater in older plants than younger plants. Once again, the "age" of a plant inherently tells us nothing. However, how old a plant is may serve as an imperfect reflection of a wide variety of factors including condition of capital equipment and the industrial traditions that define both the plant and the local-regional markets in which it functions. Together these correlates have important implications for overall productivity and industrial competitiveness.

Included in these possible correlates of age may well be a kind of "institutional arthritis" among smaller plants which influences the relative openness of a plant to the adoption of advanced production technologies. While the results in Section 3 suggest that older plants are more frequent users of new technologies, the older plants included in that study tend to be larger. Older plants included in this analysis are smaller in size and may have lost their ability over time to upgrade their physical capital. Whatever the more detailed explanation lurking within this simple fitted equation, it appears that unionized plants and older plants were particularly vulnerable to job loss compared to nonunionized and younger plants.*

Finally, a third independent variable PLANT TYPE--whether or not the plant is a single-site plant--was introduced into the model. The resulting fitted model was:

$$YP = -3.76 - 10.4\ UNION - 0.26\ PLANT\ AGE + 3.17\ PLANT\ TYPE$$

$$(-1.64) \quad (-3.04) \quad (-3.58) \quad (1.07)$$

$R^2 = .03$

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*Another model which tested for the influence of the interactive effect of union status and plant age beyond their independent effects yielded evidence of a nonsignificant relationship between employment change and the interaction of these two variables. And so, this interaction term was dropped from further analyses.

The results indicate that this more complex model is not an improvement over the leaner second model above. There does not appear to be a strong linear relationship between plant type and employment change. That is, on the average, single-site plants were neither more nor less likely to experience job gains or losses during the 1980-82 period.

4.3.5 Automation and Patterns of Industrial Renewal

A recent report on robotics prepared for the Joint Economic Committee (1982) noted that the adoption of productivity-enhancing technologies such as robots and other forms of automation have generally been made after the industry has experienced employment declines. Such an investment strategy would be logical when critical shortages of skilled machinists are experienced and when economic recovery allows more investment in capital equipment. Others have suggested that automation is used in a more calculating way to trim costs through an explicit policy of labor substitution on the part of companies, thus purposely eliminating jobs.

While the causal sequence between technology adoption and employment change is probably not fixed across all times, places or industrial circumstances, it is reasonable to view either secular or cyclical employment contraction as a sufficient incentive to prompt a company to consider upgrading its manufacturing facilities by, for instance, expanding its computer-assisted machine control programming capability. Table 4.12 reports data that indicate that for both plants that gained and those that lost employment in the 1980-82 period, at least three plants in four are planning to upgrade their computer-assisted programming capability. This is so even though this same capability is admittedly minimal for the majority of them.

Despite the common planned upgrading response across plants, it is evident that plants which experienced employment gains between 1980 and 1982 exhibited

TABLE 4.12

Employment Change (1980-82) By Plans to Expand NC/CNC Machine Control

		Production Employment Change 1980-82		
		Increase	Decrease	Total
Plans to Expand NC/CNC Capability	YES	211 (83.1%)	577 (74.9%)	788 (77.0%)
	NO	43 (16.9%)	193 (25.1%)	236 (23.0%)
Total		254 (24.8%)	770 (75.2%)	1,024 (100.0%)

greater interest in upgrading their machine control programming capacities than did plants which had experienced employment decline. It is likely that for some plants in increasingly competitive local or regional markets, the shakeout which was already underway had an air of inevitability against which those plants already weakened and losing ground expected to make little headway even if they could have afforded to adopt upgraded machining technologies. Still, the more important finding is how widespread is the commitment to adjust to competitive pressures by stepped up adoption of advanced production technology.

Finally, let us inquire about the impact of a plant's union status and right-to-work state location on plans to enhance its already advanced production technology with expanded programming capabilities. We might suspect that efforts to rationalize a plant's production facilities could well be hindered by the reduced corporate flexibility which unionization is so often accused of fostering. This would result in unionized plants being less likely to step up to newer production technologies. By contrast, the very unionization status which would be expected to cause a chilling effect on technology upgrading may just as well serve as a special inducement to substitute capital for labor and thereby gain an extra margin of control by management over a plant's operation. As is so often the case, there exist logical explanations to support logically opposed outcomes. As Table 4.13 indicates, neither speculation appears to be supported. In general, the union status of production workers does not appear to influence appreciably whether or not a plant reports planning to expand its computer-assisted programming capability.

Table 4.13 also reports the relationship between right-to-work status of the states in which the plants are located and plans to enhance programming capacity. The data indicate that whether or not a plant is located in a state with a right-to-work legal provision appears to have little discernible influence on

TABLE 4.13

Plans to Expand NC/CNC Machine Control Capabilities by
Union Status and Right-to-Work State Status of Production Workers

		Union Status			Right-to-Work State Status		
		Union	Non Union	Total	Right-to-Work State	Non Right-to-Work State	Total
Plans to Expand NC/CNC Capability	YES	184 (75.1%)	676 (77.7%)	860 (77.1%)	144 (75.4%)	742 (77.8%)	886 (77.4%)
	NO	61 (24.9%)	194 (22.3%)	255 (22.9%)	47 (24.6%)	212 (22.2%)	259 (22.6%)
	Total	245 (100.0%)	870 (100.0%)	1,115 (100.0%)	191 (100.0%)	954 (100.0%)	1.145 (100.0%)

technology upgrading decisions. Apparently, decisions concerning the adoption or upgrading of advanced production technologies are generally influenced by considerations primarily related more directly to improved productivity and competitiveness. The direct productivity benefits expected from advanced technology, rather than the more indirect benefits related to labor management, are more likely to drive the process of technology upgrading and consequent capital renewal.

Building evidence appears to suggest, then, that such automation as has taken place within small plants in the metalworking industry may well be a response to relative productivity declines tied to long-term structural changes and consequent loss of competitive position. In other words, like employment contraction itself, automation in the form of the adoption of more sophisticated machine control and programming systems, has been a response to declining industrial competitiveness. Widespread employment contraction throughout an industry which is viewed as a symptom of a restructuring regional, national or international economy may well serve as an inducement to a plant--whether it was expanding or contracting its own work force--to take steps to guard against future signs of diminished competitiveness.

4.4 Summary

The evidence provided by this nationwide survey of small plants in the metalworking industry supports a number of conclusions, all of which tend to underscore the indigenous potential retained by such plants in an otherwise beleaguered industrial sector.

The metalworking industry has long been and remains highly concentrated in its seedbed of the East North Central and Mid Atlantic regions. In recent decades this Industrial Heartland has more than held its own in the upgrading of its aggregate physical capital through new plant starts. That new growth has not come at the expense of the Industrial Heartland is borne out by the fact that plant 'births' have largely been captured by older industrial regions in recent decades. The format of growth among small plants has also involved single-plant firms rather than branching by large multi-plant enterprises.

From this survey of over 1000 small plants in the metalworking industry, the decision to adopt new machine control technology seems to be overwhelmingly driven by the desire to increase plant productivity, and the desire to improve a plant's competitive position within the industry. The urge to engage in a strategy of labor substitution in order to adjust to or put downward pressure on wages does not figure prominently in the reasons for adopting these advanced production technologies.

The metalworking industry has been the setting for widespread employment contraction during the recent recession. The greatest impact was felt in the core region (East North Central) of the industry, though more than seven in ten plants in this survey experienced job loss in the majority of the remaining regions. Older plants among this sample of smaller plants in the metalworking industry were much more likely to experience employment contraction than were younger plants. Plants with unionized production employees likewise experienced higher rates of employment contraction than did nonunion plants.

The relatively rapid spread of advanced production technologies in this industry appears to be both market-driven given the building competitive pressures in intra-regional markets, and technology-driven given that existing machine control capabilities have become available on a scale and at a price that permitted adoption by the vast majority of plants in the metalworking industry. Neither plant age nor whether or not the plant is tied to a more complex corporate structure influenced the decision to upgrade existing advanced production technology.

Finally, technology upgrading does not appear from this study to be an element in a larger strategy either to diminish the power of unions in the industry or to put downward pressure on high wages for skilled workers. If anything, the industry has had to adjust to a chronic shortage of appropriately skilled labor.

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