CHANGES IN THE ORGANIZATION OF PRODUCTION

AND

THE SKILL COMPOSITION OF EMPLOYMENT

by

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ABSTRACT

This thesis tests for a shift in the organization of production from mass to flexible production using data on the skill composition of manufacturing employment. Mass production involves high volume output of standardized goods using highly specialized, dedicated capital equipment and a division of labor that seeks efficiency by reducing to the bare minimum the number of tasks performed by each worker. Flexible production, on the other hand, refers to the production of specialized, or customized products made in small quantities using flexible capital equipment and workers who can quickly be productive at a wide and varying range of tasks. The much more demanding nature of the task structure for production workers in flexible production increases the importance of training costs relative to wages. Since skilled--more highly educated--workers are likely to be less costly to train, the shift to flexible production precipitates a relative shift in demand toward skilled workers. The testable implication of a shift to flexible production is, therefore, an increase in the employment share of skilled **production** workers in total manufacturing production employment. The results support the hypothesis that there has been a shift since the early 1970s from mass to flexible production in both the U.S. and western Europe.

The thesis is organized in four chapters. Chapter one begins with qualitative evidence which illustrates the implications of changes in the organization of production for the learning and skill requirements of workers. Next, a formal model is developed in which the firm varies its employment mix between skilled and unskilled workers as a function of relative wages, training costs and the length of product life-cycles. The model yields labor demand functions by skill groups which are used to test for a shift from mass to flexible production.

Chapter two contains the empirical tests of the model for the U.S. Data on employment composition by detailed occupation for the period 1977 to 1986 are presented which show a significant increase in the share of skilled production workers. Relative wage data show no decline for skilled workers. These facts, together, imply a shift in relative labor demand. Nonetheless, formal labor demand estimation follows using annual Current Population Survey data on manufacturing production workers for

1973 to 1985. The estimates demonstrate a shift in demand favoring skilled at the expense of less skilled workers.

While the shift to skilled workers is derived as a test of competing production modes, the fact that such an up-skilling has taken place, both in the U.S. and elsewhere, is an important finding in its own right. The unskilled have suffered significant relative wage and employment losses in recent years. Change in the organization of production is a promising explanation for these losses that transcend national boundaries.

Chapter three explores our model in the context of two countries with very different institutional structures: Germany and the United Kingdom. The first part contrasts the vocational training systems in Germany and the U.K. and makes predictions, on the basis of our model, of the implications for the skill composition of manufacturing production employment in the two countries. The second part presents employment share and relative wage data from Germany and the U.K. which confirm the central predictions that: flexible production has for decades been used more in Germany than in the U.K. or the US; the poor quality of vocational training in the U.K., coupled with the use of strict craft job demarcations, forestalled a shift to flexible production until recently; and, there has been a shift in relative labor demand favoring more highly skilled production workers in both Germany and the U.K. in recent years.

Chapter four generates further testable implications of flexible production using non-labor data. The first section considers increases in intraindustry trade (IIT) as a proxy for shortened product life-cycles. A ranking of two-digit industries on the basis of change in IIT is shown to correspond closely to a ranking of industries based on the extent of the relative shift to skilled production workers. The next section draws on recent theoretical work in which firms respond to uncertain product demand by either mass producing and using finished goods inventories to smooth production, or building to order (produce flexibly) to meet demand as it is realized. The ratio of order backlogs to finished goods inventories should rise if firms move from mass to flexible production. This prediction is confirmed for the period 1970 to 1987 using firm-level data from Compustat. These results support the shift to flexible production as the cause of the observed changes in labor demand.

The last section of Chapter examines competing explanations for the shift in relative labor demand. Secular technological change, and the outsourcing of low skilled jobs abroad are both considered and found not to be important causes of the observed changes. Recent shifts in relative labor demand arising from capital-skill complementaries associated with new, information-intensive technologies is a more likely alternative. However, the evidence suggests that new technologies have been important enablers to changes stimulated by product market conditions.

Chapter five recapitulates the main points of the thesis, and offers lessons for methodology and some broad policy recommendations on the subjects of assistance for unskilled workers and improvements in the U.S. vocational training system.

Thesis Supervisor: Michael J. Piore

Title: Professor of Economics

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INTRODUCTION

The past twenty years have witnessed a remarkable reconfiguration of the international industrial landscape, with countries such as Japan and Germany prospering while the relative positions of the United States and the United Kingdom have declined substantially. The onslaught of vigorous international competition in the U.S. markets for durable goods forced American managers and scholars to consider alternative organizational and managerial methods, and, more broadly, different institutional structures governing relationships between education, labor, business and government. Many books have been devoted to diagnosing the failures in American industry, or the superiorities in Japanese or German industry. A recent example is Made in America, the report of the Massachusetts Institute of Technology Productivity Commission. Neither this study, nor its predecessors,[1] lays blame at the door of American technology. Rather, these reports fault American managerial practice and American training institutions. Made in America, for example, argues:

> The causes of [the productivity] problem go well beyond macroeconomic explanations ... to the attitudinal and organizational weaknesses that pervade America's production system. These weaknesses are deeply rooted. They affect the way people and organizations interact with one another and with new technology; ... and they affect the way business, government, and educational institutions go about the task of developing the nation's most precious asset, its human resources. (p. 166)

In other words, the failure of the organization of production to change sufficiently in response to changes in the economic environment, and the failure of the American training system to provide an adequately trained

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[1]See, for example, the Cuomo Commission Report (1988).

workforce, lies at the heart of this country's competitive shortcomings.

The economics profession has not been enormously helpful in understanding differences in the organization of production across countries or firms. This is due in part to a preference for tractable mathematical models. However, it is largely the result of the stability of the mass production organizational structure, and the institutions that surrounded it, from the Great Depression to the early 1970s. In the midst of such stability, economists modelled a firm's reactions to changes in relative prices, demand shocks and the like, assuming no fundamental changes in firm behavior or in the organization of production.

Piore and Sabel (1984) were the first to identify the reliance of the existing American institutional structure on mass production, and to articulate the relationships between mass production and the central pillars of the American institutional structure; e.g. industrial unionism, macroeconomic stabilization policy, and educational institutions. Their work called into question the stability of mass production, and suggested that an alternative organization of production, flexible specialization, may be better suited to the more turbulent, internationalized economic environment of the 1980s.

Mass production involves high volume output of standardized goods using highly specialized, dedicated capital equipment and a division of labor that seeks efficiency by reducing to the bare minimum the number of tasks performed by each worker. Flexible specialization, on the other hand, refers to the production of specialized, or customized, products made in small quantities using flexible capital equipment and workers who can adapt to perform a wide variety of tasks. It is, in other words, a return to craft, or artisanal methods of production. Piore and Sabel describe in detail the historical antecedents of mass production and flexible specialization, and discuss the fundamental differences that distinguish the two ways of organizing production. Apart from anecdotal evidence, however, they do not provide empirical evidence for the extent to which there has been a shift in American manufacturing from mass production to flexible specialization.[2] Indeed, Piore and Sabel view the outcome of America's crisis in institutional structure to be unresolved: they argue that firms and societies must choose between mass production and flexible specialization. Furthermore, they argue that technology will not be the deciding factor: it can be used to support either scheme.[3]

Mass production and flexible specialization are polar cases defined by large volume output of a single good and low volume output of a potentially infinite number of goods, respectively. In the interior lies

[2]One important implication of the Piore and Sabel story that has been subjected to empirical scrutiny is that flexible specialization reduces any competitive disadvantages resulting from small size. Results from a recent international study (Sengenberger and Loveman, 1988) confirm that, after decades of a trend away from small establishments, there has since the late 1970s been a reversal of this trend. In each of the ten countries studied, the employment shares of small (less than 100 employees) establishments have risen since the late 1970s. There is also evidence of substantial downsizing among the establishments of large enterprises.

[3]The issue of technology's role in the story is considered in detail below.

the more common cases, described by Piore (1987) as mass production with cosmetic variation and flexible mass production. The former refers to changes in independent features of the product such as color or accessories. As such, it involves no major changes in the organization of production. Flexible mass production, on the other hand, refers to the capacity to produce a large, but finite, number of distinct products. It is the ability to produce many distinct products that requires a fundamentally different organization of production. Throughout the remainder of this thesis the term "flexible production" will be used to describe those cases where at least several distinct products can be produced. It, therefore, spans from Piore's flexible mass production to flexible specialization. "Mass production" will be used to describe the output of a single product, with or without cosmetic variation. These two more general terms are used because they capture with sufficient precision the fundamental differences in the organization of production that are at issue in this thesis, without unwieldly detail.

The empirical question of whether or not America is undergoing a shift toward flexible production is critical, since flexible production may require a very different institutional structure, and may inflict at least transitory costs on particular groups. Furthermore, if flexible production indeed enhances America's competitive position in the world, impediments to the adaptation to flexible production may be costly to our standard of living.

This thesis is an attempt to articulate a central testable implication of a shift from mass to flexible production, and to test the implication both in the U.S., and in Western Europe using a comparative methodology. The testable implication stems from an alternative theory of employment determination premised on the notion that the way in which firms go about maximizing profits has important implications for the labor market outcomes of different groups of workers. In this theory, firms make strategic choices about how to respond to changes in product markets, and these choices in turn influence their hiring decisions. Particular strategies may bode well, or poorly, for specific groups of workers. If there has been a pervasive shift in strategy that is disfavorable to particular groups of workers, these workers will have difficulty finding employment.

Flexible production, we contend, requires adaptable workers who can quickly be productive at a wide and varying range of tasks. The training component of employment cost therefore rises relative to wages as the frequency and amount of training increases, and ceteris paribus firms' labor demand shifts toward workers for whom training is least costly. Since skilled--more highly educated--workers are likely to be less costly to train, the shift to flexible production precipitates a relative shift in demand toward skilled workers. The result is a deterioration in the employment prospects for unskilled workers.

The testable implication of a shift to flexible production is, therefore, an increase in the employment share of skilled production workers in total manufacturing production employment. The focus is on production workers because it is in this employment group that a change in the nature of production should be most evident. Up-skilling among other groups, such as white-collar jobs replacing blue-collar jobs, is consistent both with a shift in the organization of production and traditional stories such as technological change and capital-skill complementarity. To the extent that employment and training institutions vary across countries, the direction of the shift to skilled workers will remain, but the details may vary significantly. In countries such as Germany, where the institutional structure has historically been better suited to flexible production, the timing and magnitude of the shift may be very different from, say, the U.K. and the U.S.

While the shift to skilled workers is derived as a test of competing production modes, the fact that such an up-skilling in production employment has taken place, both in the U.S. and elsewhere, is an important finding in its own right. The deteriorating employment prospects of less skilled workers is currently an important policy concern, in at least two respects. First, among the most perplexing facts associated with the sharp rise in unemployment in Europe has been the inability of the unemployed--particularly the long-term unemployed--to find work despite upturns in output and wage demands well within the bounds allowed by productivity growth.[4] What is perhaps less widely

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[4]See Bentolila (1988) for evidence on these stylized facts.

recognized is that the incidence of unemployment has fallen disproportionately on unskilled workers, while there are often shortages of skilled workers.[5] Similarly, Murphy and Topel (1987) have shown that long-term unemployment in the U.S. has increasingly fallen on male production workers with stable work experiences who heretofore were rarely found in long-term unemployment.

Two implicit assumptions underlying the work on unemployment[6] are that firms are going about doing what they have always been doing--maximizing profits--and the only changes in their behavior result from changes in constraints, relative prices and demand shocks; and, that workers are sufficiently homogeneous as to be considered one aggregate input. This thesis provides an alternative framework in which firms do not wish to hire low skilled workers, even at very moderate wages.

Second, there has been considerable research recently, discussed in detail below, which documents a severe decline since 1979 in the relative wages of less skilled workers in the U.S. This decline reverses a long-standing trend in the other direction, and is particularly notable given the significant increase in the relative supply of more highly educated workers. The research on changes in the wage structure, too, explores a variety of explanations premised on organizational stability within firms. The current state of that research suggests that change in the organization of production is a promising explanation for the unexplained

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[5]See Blanchard (1988).
[6]See Bentolila and Bertola (1988) and Blanchard and Summers (1986) for the state of the art in this field of research.

within-industry relative wage and employment losses suffered by the less skilled. Furthermore, the findings of this thesis show that the employment prospects for unskilled workers have deteriorated for reasons that transcend national boundaries, which further indicates the need for explanations that are not idiosyncratic to the U.S.

The thesis is organized in four chapters. Chapter one develops the qualitative story and formal model of changes in the organization of production that underlies the remainder of the thesis. It begins with a brief review of the Piore and Sabel (1984) characterization of mass production and flexible specialization. Several case studies are then discussed which illustrate the implications of changes in the organization of production for the learning and skill requirements of workers. These case studies provide a detailed view of work on the shop floor that makes concrete the increased range of tasks that are involved in flexible production.

The first Chapter concludes with the presentation of a formal model of firm behavior. The firm hires two kinds of workers, skilled and unskilled. These workers must be retrained each time a new product is introduced, and the training costs are lower for the skilled workers. The firm varies its mix of employment as a function of relative wages, relative training costs and the length of the product life-cycle. Differences in employment and training institutions across countries influence the skill mix of employment via the relative cost and supply of skilled workers. The model yields labor demand functions by skill group which are used to test the central hypothesis that a shift from mass to flexible production results in an increase in the relative demand for skilled production workers. Finally, model simulations are presented to examine the behavior of relative wages and employment shares when firms move from mass to flexible production.

Chapter two contains the empirical tests of the model for the U.S. It begins by presenting what little data are available on product life-cycles. Data on employment composition by detailed occupation are then used to construct three skill groups for durables manufacturing production workers over the period 1977 to 1986. The data show a significant increase in the share of skilled workers. Relative wage data for similar groups show no decline in the relative wages of skilled workers. These facts, together, imply a shift in relative labor demand. Nonetheless, formal labor demand estimation follows using annual Current Population Survey data on manufacturing production workers for 1973 to 1985. Since panel data on product life-cycles do not exist, a simple time trend is used to proxy for reductions in the length of product life-cycles over the period. The estimates demonstrate a shift in demand favoring skilled at the expense of less skilled workers. The results are robust to a variety of specifications and estimation techniques. Since the share of total production employment has declined as that of professional and technical workers has risen, the employment prospects of unskilled production workers have deteriorated severely.

The last section of Chapter two reviews previous work on labor demand by skill group, and discusses the empirical results in the context of research on changes in the relative wage structure in the U.S. Several authors have found a recent sharp rise in the relative wages of more highly educated workers; e.g., college versus high school graduates. While this research involves data on workers in all industrial sectors and focuses on educational rather than occupational groups, the findings of this thesis address the current missing link in the relative wage structure literature: an explanation for the within-industry shift in relative labor demand favoring more highly educated (or skilled) workers.

Chapter three explores our model of changes in the organization of production in the context of two countries with very different institutional structures: Germany and the United Kingdom. Training systems determine the relative cost and supply of different skills in the labor market, and in our model they, in turn, affect how production is organized. The first part of this chapter contrasts the vocational training systems in Germany and the U.K., and makes predictions, on the basis of our model, of the implications for the skill composition of manufacturing production employment in the two countries. This international comparative methodology is a very powerful and underutilized tool for distinguishing among competing theories. Variance in institutional structures generates additional testable hypotheses, while other variables, such as technology, are essentially held constant across countries.

The second part presents employment share and relative wage data from Germany and the U.K. The data confirm the central predictions that: due to its extensive vocational training program, flexible production has for decades been used more in Germany than in the U.K. or the US; the poor quality of vocational training in the U.K., coupled with the use of strict craft job demarcations, forestalled a shift to flexible production until recently; and, there has been a shift in relative labor demand favoring more highly skilled production workers in both Germany and the U.K. in recent years. The final section presents two case studies. The first illustrates the shift to flexible production in the U.K. motor vehicles industry, while the second compares the different organization of production in the machine tool industries of Germany and the U.S.

Chapters one and two present the model and test it using labor data. However, since product life-cycle data, or other measures of volatility in product markets are not available, the cause of the observed shift in labor demand remains open to debate. Chapter three uses international comparisons to generate unique implications of flexible production as the source of changes in manufacturing production employment composition. Chapter four continues in this vein by using non-labor variables to generate testable implications of flexible production. The first section considers increases in intraindustry trade as a proxy for shortened product life-cycles. Intraindustry trade, it is argued, is a consequence of business strategies based on product differentiation and flexible production.[7] Intraindustry trade indices are calculated for each two-digit S.I.C. manufacturing industry and a ranking is made on the basis of the increase for the period 1974-84 over the period 1958-73. This ranking is shown to correspond closely to a ranking of industries based on the extent of the relative shift to skilled production workers. Hence, if increases in intraindustry trade are a valid proxy for reductions in product life-cycles, then these results support the shift to flexible production as the cause of the observed changes in labor demand.

The next section draws on recent theoretical work by Milgrom and Roberts (1988a,b) that models mass versus flexible production as two means for responding to uncertainty in product markets. Firms may either mass produce and use finished goods inventories to smooth production, or build to order (flexibly) to meet demand as it is realized. Milgrom and Roberts argue that the ratio of order backlogs to finished goods inventories should rise if firms move from mass to flexible production. This prediction is tested for the period 1970 to 1987 using firm-level data from Compustat. Changes in accounting methods for inventory valuation complicate the analysis, but the results from a battery of tests indicate an increase in the ratio of order backlogs to finished goods inventories after controlling for other variables known to influence inventory behavior. Rankings of the manufacturing industries on the basis of the increase in this ratio and the shift to skilled workers yield mixed

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[7]The relationship between this argument and Krugman's (1981) model is discussed in Chapter four.

results. Nonetheless, the overall results generally support the hypothesis of a change from mass to flexible production.

The last section examines competing explanations for the shift in relative labor demand. Long-term increases in the employment share of skilled workers as a consequence of secular technological change, and the outsourcing of low skilled jobs abroad for cost-cutting purposes are both considered and found not to be fundamental causes of the observed changes. Recent shifts in relative labor demand arising from capital-skill complementaries associated with new, information-intensive technologies is a more likely alternative. It is discussed in some detail, with the conclusion that new technologies have been important enablers to changes stimulated by product market conditions.

Chapter five recapitulates the main points of the thesis, and offers lessons for methodology and some broad policy recommendations on the subjects of assistance for unskilled workers and improvements in the U.S. vocational training program.

It is important to point out at the beginning that this thesis pursues a methodology that is atypical of conventional economics. It begins by asking a broad question based on case study evidence and existing research. A formal model is introduced to clarify the discussion and generate testable implications. However, crucial variables (e.g. product life-cycles) in the model, and in the more general discussion, are not observable in large samples. It is this lack of data that forces the methods that follow. First, a test consistent with the implication of the model is conducted (i.e. the tests for a shift in relative labor demand). Second, international comparative analysis is used to bring variance in institutional structures to bear to generate unique hypotheses that depend on observable cross-country differences. Third, non-labor implications of a shift to flexible production are tested to further delineate this from competing explanations for the shift in relative labor demand. Finally, the merits of other explanations are considered explicitly.

The objective is to build a mosaic of evidence which can be used to evaluate the central hypothesis of a change in the organization of production from mass to flexible production. While it does not have the flavor of a demonstration that a unique proposition has been proven to the exclusion of all others, this thesis does provide substantial empirical evidence on a broad and hopefully important issue that has heretofore not been subjected to this type of scrutiny.

CHAPTER I

A Model of Changes in the Organization of Production and the Demand for Labor by Skill Group

A. Mass Production and Flexible Specialization

The title of Piore and Sabel's (1984) book, The Second Industrial Divide, refers to a period in which a choice exists between two "technological trajectories": mass production and flexible specialization. The first such occasion occurred during the nineteenth century, when firms in more industrialized countries pursued mass production.[8] The strategy of large firms was to reduce unit costs via long runs of standardized products, and collect the rents associated with imperfect competition in product markets. Stability was critical in this system because the extensive division of labor and use of inflexible, dedicated capital equipment, and the reliance on scale economies to generate profits, made instability in input supply (strikes), output demand, and prices very costly. For example, large changes in input prices were

[8]Small firms filled a special, largely subordinate role in this system. They produced for specialized markets, and the precarious nature of their business necessitated flexible production; i.e., more general labor and capital. Indeed, their production was characteristic of craft work: relatively small capital stocks and relatively many highly skilled craft workers.

costly because the rigid nature of the production technology did not permit easy substitution of inputs. Instability in output prices was a problem insofar as price reductions rendered production unprofitable, and it was not possible to quickly move into the production of alternative products. The skill mix of employment in mass production firms reflected the extensive division of labor, as a very large portion of employment consisted of semi and unskilled production workers who manned and supported assembly lines.

The OPEC shock in the early 1970s began a period of institutional crisis, Piore and Sabel argue, as the existing institutional structure failed to respond well to a different economic environment. The economic environment of the 1970s featured a breakdown in stability and growth in most Western countries, evidenced by sharp and unpredictable changes in raw materials prices, an increase in international competition in product markets (especially in markets formerly dominated by a few large producers), floating exchange rates, very rapid technological change, and an unexplained slowdown in productivity growth.

The crisis presents an opportunity to choose again between the alternative technological trajectories. A large and growing international literature, based largely on case studies, now exists to document that manufacturing firms are responding to greater international competition, shorter product life-cycles, rapid changes in factor prices, and a general increase in uncertainty by pursuing a fundamentally different strategy: flexible production.[9] Rather than seeking to gain market power in markets for standardized goods, firms are attempting to produce high quality, innovative and customized products. Rapid development and introduction of new products in response to market changes is a primary goal, as are timely delivery and customer service. The objective is to create and serve product niches that, unlike commodities, are less vulnerable to low cost competition, particularly from less developed countries. Flexible production allows producers to respond quickly to changes in demand or relative prices, thus mitigating the slow adjustment and consequent losses characteristic of mass production. The following section presents some case study evidence from large firms that have undergone the transformation from mass to flexible production.

B. Qualitative Evidence on Flexible Production and Skill Requirements

Evidence on the shift from mass to flexible production, and the causes of the shift, consists almost entirely of case studies of specific firms, industries and regions. While no attempt is made here to survey this literature - Sabel (1988) accomplishes this task in part - the central theme is that increased product market competition and greater economic turbulence led firms to favor flexible production. The examples that follow are used to show how flexible production differs from mass production, and to identify the characteristics of flexible production most salient for changes in the skill composition of employment.[10]

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[9]See Sabel (1988) for a survey, and Locke (1988) and Piore (1987) for specific case studies.

[10]While the focus of this thesis is primarily on the U.S., Italian case studies are used because of their rich detail on changes in the task structure and learning requirements for production workers. American

Frederico Butera (1975) describes the shift from a strategy of mass production to flexible production at Olivetti in the 1970s:

> The character of Olivetti's market has changed; it is more specialized, more differentiated in terms of performance requirements, more demanding in terms of technical quality, and, above all, subject to stronger competition. To be successful in these markets the company must not only offer competitive prices and very high quality; chiefly, it must also supply a wide range of products and constantly improve them to meet customers' requirements. As a consequence, for example, the company's catalog grows larger, since each product is supplied in an increasing number of models, and the products' lifetimes are considerably shorter. (pp. 167-8)

The ramifications for the organization of production and skill requirements were substantial. Previously, mass production was conducted using long assembly lines along which each assembly operation was a short, simple task. Workers had no knowledge of the mechanical function of the assembled pieces, and were trained only to meet the pace of the line. Inspection, repair, and supervision were provided by three other groups of workers.

In the new flexible production regime, the long assembly lines are being replaced by several subassembly units, each of which produces one

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examples may be found in Zuboff (1988) and Hirschhorn (1986). A comparison of work organization in U.S., Japanese and European textile mills is made in the textile industry study in Dertouzos, Lester and Solow (1989).

functional and testable part of the product (e.g., the printer or the tabulator in a calculator). These parts then go to a very short final assembly line where they are combined to yield the final product. Thus, rather than dividing production into many sequential steps, the new process involves parallel production by several subassembly units. Each worker is now involved in the production of a mechanical assembly, rather than just one step, and more importantly, is responsible for inspecting and repairing his/her own work, acquiring his/her own supplies, and substituting for absent workers in the production unit. Butera notes:

> The worker is trained to know not only the sequence of the assembly operation he performs but all the functions and mechanical principles of the subproduct on which he works. The type of training given to the assembly [worker] is no longer only an investment for the specific job, but improves the basic professional education of the worker.... The greater accumulation of basic knowledge by workers means that it is easier to transfer personnel, and high mobility has been a major feature in recent years. (pp. 179-193)

Butera concludes that short product life-cycles reduce the time available for reorganizing work using a detailed division of labor and favors production in flexible cells of more generally trained workers.

Locke (1988) discusses Fiat's efforts in the 1980s to increase its product differentiation by shifting from "a few poorly differentiated models to many new models with frequent restyling" (p. 3). Like the Olivetti product, Fiat cars are now made of interchangeable parts that are assembled along with components particular to each model to produce a wide range of final products. The modular production system also allows innovations in each component without overhauls in the model itself.

Locke argues:

> By...rediscovering artisanal modes of production and coordination, car makers are disaggregating their activities into autonomous but coordinated units specialized in particular aspects of production along the lines of flexible specialization. Developments like integrated engineering, decentralized production and the formation of polyvalent workers are...evidence of this trend. (p. 49)

Finally, Horst Kern and Michael Schumann have been collecting case study material in West Germany, and have published a volume of these studies that is, unfortunately, available only in German. However a recent paper by Kern and Schumann (1988) summarizes the main findings:

> Work today has a very different function than it did when traditional manufacturing processes were used. Human work is no longer direct: it no longer involves more or less immediate contact with materials and products. Instead, it encompasses activities such as planning, regulating and controlling. This kind of work resists division. In fact it is most efficient when combined with functions such as upkeep of machinery and inspection of the finished product. This new, more synthetic approach redefines factory jobs.... The need for theoretical competence is rather high, too high at least for on-the-job training. Professional training is necessary. (p. 15)

This research suggests that flexible production involves the reorganization of work away from narrow repetitive tasks based on an extensive division of labor, and toward groups of tasks spanning very different activities that require a conceptual understanding of the production process. The next section develops a simple model of firm behavior in which changes in the length of product life-cycles trigger changes in the composition of employment, as firms seek workers who are most efficient at performing a wide and varying range of tasks.

C. A Formal Model

When firms were in the business of mass production, stable products and production processes permitted the amortization of training costs -- such as were required -- over the very long period during which the product was being produced. In most cases, mass production involved many jobs with narrow, highly repetitive tasks requiring little training or skill. Since the tasks were so narrow and far removed from the rest of the production process, workers performing these tasks had little by way of general or formal training, and most workers lacked any "conceptual" knowledge of the production process. Conceptual knowledge refers to an understanding of the interdependencies between the various parts of the production process; an understanding of each step and the mechanisms that link them. This very general and holistic knowledge of the production process may be contrasted with the "customary" knowledge of an unskilled mass production assembly worker, who knows only the task required of him and lacks any broader knowledge of the overall process.[11]

When production is less stable--products change rapidly and are less standardized--it is precisely this conceptual knowledge of production that is necessary for workers to respond effectively to changing tasks. When workers are asked to perform a rapidly changing set of tasks, they must have an understanding of how the tasks can be reconfigured and how

[11]For elaboration on the general distinction between conception and execution see Piore (1968) and Braverman (1974).

their work fits into the new production process. In the absence of such a conceptual understanding, the training costs necessary for changes in the production process would be prohibitive. Furthermore, if flexible production is enhanced by team work--in particular, team work involving very different occupations such as engineer and production worker--conceptual knowledge is vital.[12] Production workers must communicate effectively with other team members. If each production worker knows nothing more than his specific task, then team work is essentially fruitless.

A conceptual understanding of production may come from formal training, on-the-job training, or some combination. The cost to the firm of training a worker sufficiently so as to perform some changing basket of tasks required by flexible production varies inversely with the level of training already received by the worker.[13] The cost is therefore less for highly skilled workers than for unskilled workers. Since flexible production involves frequent training in order to adapt to new products and processes, and since the amortization period is consequently shorter than in mass production, firms will increasingly favor the employment of skilled workers at the expense of unskilled workers, for given relative wages.[14]

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[12]Furthermore, it behooves firms to have workers actively involved in the innovation process, and this participation is much more likely to come from workers who understand the big picture.
[13]It may also be the case that existing training signals higher worker ability, which acts to further reduce training costs.
[14]Small firms have always employed relatively more skilled workers and fewer un and semi-skilled production workers than have large firms, because small firms have always been more flexible producers. The shift to flexible production by large firms is now tending to move their

These insights can be captured by a model in which, for simplicity, the multiple factors that have increased instability in product markets are represented by an exogenous shortening of the product life-cycle.[15] Consider a firm with monopoly power during the life of a product. Reductions in the length of product life-cycles are, then, the source of increased volatility in product markets that induces flexible production (data on product life-cycles are discussed in Chapter II). In this model a product life-cycle refers to the period over which a firm producing the product can capture an economic rent. The firm has market power in the product market and can charge a price greater than marginal cost for a period of time, after which entry by competitors drives down the price to marginal cost. This definition is different from the norm, which refers to the period over which a product is produced, irrespective of rents. Product life-cycles defined in the former way are a good proxy for product market volatility because they capture the effects of heightened competition, regardless of the source of the competition.[16]

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employment mix increasingly toward that of small firms. See Sengenberger and Loveman (1988)

[15]If there has been a shift to flexible production, the ramifications for the skill composition of employment proposed above are likely to result irrespective of what caused the shift. Technological change, for example, may favor flexible production, resulting in a shift toward skilled workers akin to that resulting from shortened product life-cycles. We focus on product life-cycles because they are a multi-faceted indicator of heightened product market competition.

[16]Entry by domestic firms, import competition, technological change and innovation all act to shorten the period over which a firm has market power for a given product.

A stream of products are assumed to be available to the firm; entry/exit decisions are not modelled explicitly. Each product has a life-cycle of length q_t, where t indexes the products. The firm must train its workers in order to produce each new product, and this cost is incurred irrespective of the length of the product life. Labor input is some basket of tasks, which can be done either by skilled or unskilled workers. However, the training costs associated with the skilled workers are less than those associated with unskilled workers (note that these training costs are not those normally observed, since workers of different skill levels are typically trained to perform different jobs). The firm pays the training costs, and takes the worker as he\she arrives at the door each period. Therefore, international variation in training institutions will affect the model's outcomes in different countries.

Finally, the model is not one of technology choice: the production function is stable over time. There are three reasons for pursuing this approach: first, modelling technology choice is a very involved endeavor, sufficiently so as to be the focus of a study rather than a detail (see Fine and Li, 1987); second, if flexible production technology itself increases the relative demand for skilled workers, as the case study evidence suggests, then our model will understate the magnitude of the employment shift by skill level; and third, the empirical work that follows is sufficiently general to allow a mid-stream change in production technology.

The problem facing the firm, then, is to choose S_t and U_t to maximize:[17]

$$q_t[P_t(Q_t)*Q_t - w_s*S_t - w_u*U_t] - t_s*S_t - t_u*U_t \qquad (1)$$

where $P_t(Q_t)$ = price for product t;
Q_t = output of product t = $f(S_t,U_t)$;
w_s = wage of skilled worker;
w_u = wage of unskilled worker;
S_t = quantity of skilled workers;
U_t = quantity of unskilled workers.
t_s = training costs for skilled workers;
t_u = training costs for unskilled workers.

q_t multiplies the conventional revenue stream less wage costs but not the training costs, because the training costs are incurred for each product irrespective of the length of its life-cycle.

Consider now the first order condition with respect to S for an arbitrary product t:

$$q_t[P'Q_s*Q + P*Q_s - w_s] - t_s = 0 \qquad (2)$$

or

$$P'Q_s*Q + P*Q_s = w_s + (1/q_t)*t_s \qquad (2')$$

An analogous first order condition obtains for U_t. Assuming a Cobb-Douglas production function and linear product demand, (2) can be written

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[17]This model can easily be extended to include dynamics by making current period training costs a function of worker tenure with the firm. In this case firms have an incentive to maintain a stable core of skilled workers, because turnover is costly in terms of training. While the dynamic model is more realistic, its implication for the shift in labor demand by skill group is not fundamentally different from the simpler static model. Therefore, since the empirical model is also static, we present the static model here.

explicitly as:

$$S = \{[(a(\alpha T_u)^{\beta})/2b(\beta T_s)^{\beta}] - [(T_s{}^{1-2\beta}(\alpha T_u)^{2\beta}) / 2b\alpha\beta^{2\beta}]\} \quad (3a)$$

$$U = \{[(a(\beta T_s)^{1-\beta}) / (2b(\alpha T_u{}^{1-\beta})] - [(\beta^{1-2\beta}) / (2b\alpha(\alpha T_u)^{1-2\beta}(T_s{}^{2\beta}))]\} \quad (3b)$$

where:

$Q = S^{\alpha}U^{\beta}$;
$P = a - bQ$;
$T_s = (w_s + (1/q)t_s)$;
$T_u = (w_u + (1/q)t_u)$.

The first order condition (2') shows what is different in this formulation from the standard case. Firms face training costs which grow in importance as the product life shortens. The shift to skilled labor results from the increased importance of training costs as q shortens. The firm now equates the value marginal product with the wage plus a training cost variable that is a function of q. For a given wage vector and $t_s < t_u$, as q_t goes to zero the firm shifts increasingly to skilled workers. This can be seen by first solving for S/U and then differentiating to find d(S/U) / dq:

$$S/U = (\alpha T_u) / (\beta T_s) \quad (4)$$

Noting that initially relative wages equate marginal products less training costs, it is straightforward to show that d(S/U)/dq is negative so long as $t_s < t_u$. Thus, reductions in product life-cycles increase the share of skilled workers in total production employment. It is important to emphasize, however, that the shift to skilled workers depends on reductions in q. If a firm simply shifts from mass production of one product to mass production of another, perhaps for international trade purposes, they will continue to use the cheaper unskilled workers to the greatest extent possible by specializing tasks and amortizing any training costs over the long period of production of the new product. For plausible values of q, t_s and t_u, it is quite possible that the training cost component rivals the wage in magnitude. It is shown in the following paragraphs that, barring severe wage reductions by unskilled workers, employment shifts to skilled workers as q declines.

In a classical economy with fully-equilibrating relative prices, there need be no shift toward skilled workers so long as the wages of unskilled workers decline sufficiently. A simulation of the model, however, shows that the wages of unskilled workers are not likely to fall enough to maintain their employment share as q declines. To make this point concrete consider a simulation, based on parameter values from the data presented in this paper, of the relative wage reductions needed for unskilled workers to maintain a stable employment share when q declines. The computer product life-cycle data given in Table 1 (discussed in Chapter II) suggest that q has declined by at least one-half from the mid-1960s to the mid-1980s. Therefore, the simulation is a linear decline from $q = 1$ to $q = .5$. Data from the Current Population Survey (Table 6, also discussed in Chapter II) suggest that the wage ratio for skilled workers (craftsmen, foremen and kindred workers) versus unskilled workers (operatives and laborers) was roughly 1.3 in the late-1970s. Suppose that the higher wage for skilled workers was purely the market's valuation of differential training costs:

$$w_s = w_u + (1/q_t)*t_u = w_u + t_u$$

where, for simplicity, we normalize t_s=0 and set the initial value of q_t = 1. It is straightforward to solve (4) for the values of w_u needed to keep S/U constant as q falls. We impose equilibrium factor shares for S and U equal to those observed in the late-1970s: .3 and .7, respectively (see Table 6).[18]

Chart 1 shows the results of two simulations. The dashed line shows the simulated value of w_u, which falls thirty percent over the ten periods. Thus, even if the technology is stable, the increased importance of training costs when product life-cycles are shorter requires substantial relative wage reductions in order to maintain stable relative employment of unskilled workers.

If firms respond to a decline in q by altering their production technology in a way that, ceteris paribus, raises the marginal product of skilled vis a vis unskilled workers, then the reduction in w_u necessary to keep S/U unchanged is significantly larger (it was shown in Section B

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[18]Note that since we have assumed $w_s = w_u + t_u$, the wages inclusive of training costs are equal, and the factor shares in the model are equal to the employment shares.

above that such changes in technology have taken place).[19] The dotted line in Chart 1 gives the path of w_u when the output elasticity on skilled workers in the production function increases uniformly from .3 to .4, while that of unskilled workers declines accordingly. In this case the results are even more dramatic: by the end, w_u must decline by more than 75% relative to w_s to keep S/U constant.

The simulated changes in relative wages are well beyond any plausible range of market adjustments. For example, Chart 2 shows the ratio of the wage for skilled production workers to the statutory minimum wage, normalized to 1973 = 1. Even this ratio, which is intended to use an extreme proxy for unskilled worker wages in the U.S., varies within a small range over most of the period.[20] Furthermore, Freeman and Medoff (1984) report that the widely heralded wage concessions of the early 1980s reduced labor cost per worker by 7-12 percent in the auto industry, and by 10-15 percent in the airline industry.[21] The simulations suggest that even if these were relative wage reductions, they would be insufficient to prevent S/U from rising as q falls. Time series data on relative wages presented in Chapter II below suggest that they have changed very little in recent years, which leaves employment to adjust to changes in q.

In sum, the foregoing model shows formally why flexible production

[19] For example, at Olivetti.
[20] Only from 1981 to 1985, when the minimum wage was unchanged in nominal terms, does the ratio move significantly. Of course, when the minimum is reset the ratio falls accordingly.
[21] These are nominal cost reductions. Given inflation, the real wage reductions were larger, but still low vis a vis the simulated relative wage reductions for unskilled workers.

entails the increased relative employment of skilled workers, and yields a labor demand equation to test for the shift to skilled workers. The next chapter takes these implications to the data.

CHAPTER II

Empirical Evidence on Shifts in Relative Labor Demand in the U.S.

A. Evidence on Product Life-Cycles

Economic theory does not provide a clear definition of product life-cycle: it is a term used idiosyncratically by business managers to suit the particular circumstances of their production process. Hence, data on product life-cycles are very difficult to find. In general, it is very hard to define a new product as distinct from a refinement of an existing product. Two plausible and measurable definitions of product life-cycle are the total period over which the product is being sold, and the period between the peak sales of a product and its successor. Table 1 is an effort to shed some empirical light on changes in product life-cycles. It shows annual shipments by model family for medium and large-sized computers manufactured by International Business Machines (IBM) and Digital Equipment Corporation (DEC).[22] Two points are clear from Table 1:

- product life-cycles have shortened;

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[22]These unique time series have been aggregated into model families on the basis of expert opinion as to what constitutes substantially different products. The opinions are those of the firm that collects the data, International Data Corporation.

- the number of distinct products on the market at any one time has risen enormously even within size classes.

By either definition, IBM and DEC product life-cycles have declined substantially. For example, the IBM large-sized 360/50 model was introduced in 1965 and sold for six years until being replaced in 1971 by the 370, which sold for seven years. Since 1978, however, there have been four product groups introduced, each of which has had a substantially shorter life on the market. Using the other definition, the peak sale of DEC's first offering, the 1040/50, occurred in 1969, and the peak sales of the successor model did not occur until 1976. Thereafter, peak sales of subsequent models arrived much more quickly, as new product introductions were more frequent. Of course, it is not possible to know what the life-cycles will be for models still being sold in 1987.

IBM and DEC have also increased greatly their degree of product differentiation. The number of distinct products for sale at any one time within a given size class has risen from one to as many as six or more. The IBM 4300 series, for example, featured more than twenty-five models from 1979 to 1985 alone, and DEC introduced six models of its mid-sized VAX computer in just over one year. The implications of these developments for production are striking. While in previous years the firms produced, wrote software for, serviced and supported only one model family, they now must do the same for many model families. Furthermore, since demand is split among several products, mass production of each is less attractive than if total shipments were accounted for by fewer models.

IBM and DEC do not constitute a representative sample, and more research is certainly called for. However, these data clearly suggest that product life-cycles have shortened significantly in this large industry.[23] Furthermore, recent work by Clark, Chew and Fujimoto (1987) suggests that increased international competition in the auto industry has led to shorter product development times and, hence, shorter product life-cycles.[24] Their research focussed on the product development process in European, American and Japanese auto manufacturing companies. The authors attributed much of the substantial Japanese advantage in product development time to fundamental differences in the organization of the new product development process. They found that after many years of international competition, American firms were re-organizing along Japanese lines, favoring the use of multi-function teams, and reducing their deficit in product development time.[25]

B. Changes in Employment Mix and Relative Wages by Skill Group: Manufacturing Production Workers

It is not possible, or even sensible, to identify a date at which

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[23]Data on personal computers, currently being collected by Ernst Berndt, indicate a similar result.
[24]If new products are developed faster, life-cycles decline unless the product line increases each time a new product is introduced.
[25]Product development time, or lead time, is the time needed to bring a product from its inception to production. The average reported in this study was 43, 62 and 63 months for Japanese, American and European projects, respectively.

the shift from mass to flexible production occurred. Firms, affected by broadly similar forces, reacted at different times and with varying speed according to their own circumstances. Indeed, there is no reason to believe that the shift took place with equal force in all industries, since changes in product life-cycles and volatility in product markets may have varied significantly across industries. In aggregate data, however, a fundamental implication of the model is that the share of skilled workers in total production employment should have risen since the early 1970s as the length of product life-cycles declined.

Data on employment and wages by skill group and industry are difficult to come by, particularly prior to recent years. Census employment data are available, however, since 1900. The top panel in Table 2 shows employment shares in the nonfarm economy by broad occupational group from 1900 to 1950. The share of production employment fell significantly as the share of clerical employment rose. The second panel shows two series for craft and operative employment as shares of production employment; the first includes construction craft occupations, while the second does not. What is striking in both series is that the share of craft employment changed very little from 1900 to 1950, while the share of operative employment increased substantially. Operatives are semi-skilled persons working with machines, and their relative employment increase reflects the rise of mass production over the period.

The lower half of Table 2 shows manufacturing occupational employment shares for 1950 to 1970. The relative movement out of production employment continues, but now the increase is found in the managerial, professional, technical and sales group. Within production employment, however, the broad craftsmen, foremen, and kindred workers group rose only three percentage points over the twenty year period. The census occupational data, as presented, are highly aggregated: they do not, for example, disentangle occupational shifts within specific manufacturing industries from employment shifts across stable industrial occupational structures. They also do not measure increased skill requirements within occupations. They are intended only to make the point that prior to the 1970s there had not been a significant increase in the share of skilled workers in manufacturing production employment. It is, therefore, not the case that a shift to skilled workers in recent years is simply the continuation of a long-term trend.

Two new data sources emerged in the 1970s providing detailed employment levels by occupation and industry. The first and best are the Occupational Employment Statistics, which, beginning in 1977, provide employment levels by detailed occupations for two-digit SIC manufacturing industries every three years. These data, published by the Bureau of Labor Statistics, are drawn from state-administered surveys of the complete population of establishments with 250 or more workers, and a sample of smaller establishments. Each occupation has corresponding Standard Vocational Preparation (SVP) codes, which give the amount of training "required to learn the techniques, acquire information, and develop the facility needed for average performance.... The training may be acquired in a school, work, military, institutional or vocational environment." It is thus possible to assign a training level to each of the approximately 110 occupations in the production worker category. There was an occupational redefinition coincident with the 1980 U.S. Census, which fell between the 1980 and 1983 survey in these data. The redefinition was quite minor for production occupations. Where differences occurred, the occupations were linked using the SVP codes.

Once each occupation has a SVP code, consistent aggregate occupational groups can be formed for the years 1977, 1980, 1983 and 1986.[26] Employment shares may then be tracked over the ten year period. This exercise was carried out on data for production workers in the four largest durable goods industries, which together account for roughly one third of manufacturing employment. Skilled occupations are those requiring at least two years training, and include jobs such as tool and die makers, machinists, electronic instrument repairers and foremen. Semi-skilled occupations require more than three months and less than two years training, and include many machine setters and operators and some assemblers. Unskilled occupations require less than three months training, and include simple assembly, material moving and laborer jobs. These particular training-based groupings are consistent with those recommended by the Bureau of Labor Statistics.

Table 3 reports the results, which show a significant increase in the share of skilled production workers in three industries, but not in electrical machinery. Electrical machinery shows no shift toward skilled

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[26] I am grateful to the B.L.S. for providing the unpublished 1986 data.

workers, but exhibits a very large shift from unskilled to semi-skilled workers.[27] It is important to note that the method used in deriving these statistics assumes no change in skill levels within occupational groups, which will understate the true change if there is also upskilling within occupations or groups of occupation. Much of the qualitative evidence suggests that upskilling within production occupations is a significant component of the reorganization of work for flexible production. If this is the case, then our method for measuring the skill composition of employment may be a significant underestimate. In addition, the reclassification of assembly occupations between 1980 and 1983 was handled by assigning the same skill composition for assemblers observed in 1983 to 1977 and 1980. This is a conservative technique since it removes any upskilling from the large assembler occupations.

The increase in the share of the more highly skilled groups proceeds from 1977 to 1983. Given that 1983 was near the trough of a deep recession, one might expect the share of skilled workers to decline by 1986 as expanding output induces rehiring of lower skilled production workers. However, the shift to higher skilled workers was reinforced in the years 1983 to 1986, despite the growth in employment and output. Table 4 shows total production employment figures and the aggregate skilled worker employment share for all four industries. The total

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[27]It is interesting to note the small share of skilled workers in the electrical machinery industries in the U.S., Germany and the U.K. Apparently, the production technology of this industry was relatively intensive in its use of lower-skilled workers, and any shift so far in the U.S. has been toward semi-skilled workers.

increase is over five percentage points -- seventeen percent of the 1977 share -- and it survives the cyclical upturn from 1983 to 1986.

While there was an increase in the relative demand for skilled workers within production employment, the broader occupational composition of employment continued to shift as it had from 1950 to 1970. Table 5 shows that the share of production and service employment fell by as much or more from 1977 to 1986 in three of these industries than did the same share in total manufacturing from 1950 to 1970. Meanwhile, professional and technical employment -- a subcategory of M, P&T, S -- grew almost one for one with the decline in the production share. Taken together with the results from the previous tables, this presents strong evidence for an increase in the relative demand for skilled workers.

Demonstrating increases in employment shares is not, of course, the same thing as demonstrating changes in relative demand, since changes in relative wages or other factors may have been responsible for increased relative employment in the confines of stable demand. Two methods are pursued to show that the observed movements in production employment shares are not cases of stable demand responding to changes in relative wages. First, Charts 3A and 3B plot the relative wages of skilled production occupations versus those of various semi and unskilled occupations. These figures show that relative wages have remained remarkably stable since the early 1970's.[28]

[28] These figures are constructed using unpublished CPS wage data, generously provided by the BLS.

If the changes in employment shares had been the result of shifts in labor supply along a stable labor demand function, then the relative wages of skilled workers should have fallen. In order for the employment share of skilled workers to have risen and their relative wages not to have declined, labor demand must have shifted outward. Consider two simple cases. In the first, the employment share of skilled workers rises, and relative wages remain unchanged because both labor demand and labor supply shift out.[29] For the second, assume that labor supply to manufacturing is very elastic: high relative wages in manufacturing induce workers to queue for jobs at the going wage.[30] In this case, shifts in labor demand alone yield the observed result, since employment is demand determined. If unions set relative wages, then relative employment may respond to shifts in demand while relative wages move very little.[31]

It is worth noting that the failure of relative wages of skilled workers to decline is surprising, given the changes in demographics. Freeman (1979) argued that the influx of a large cohort of young people in

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[29] The labor force grew over the period, and data on educational attainment do show a significant increase (fewer people had less than 12 years education, and more people had 16+ years), but the median number of years completed changed very little. Furthermore, labor supply to manufacturing for unskilled jobs is likely to have been very elastic to begin with. It is therefore difficult to know to what extent the labor supply function for manufacturing shifted out.

[30] See Loveman and Tilly (1988) for evidence on relative wages between manufacturing and other sectors.

[31] Freeman and Medoff (1984) present considerable evidence that unions, in fact, take wages out of competition and tend to reduce wage inequality within production employment.

the early-1970s reduced their earnings below what standard human capital models would predict. One implication of his findings was that as the cohorts of young, relatively unskilled workers entering the labor market in the late-1970s and early-1980s became smaller, the relative wages of unskilled workers would rise given stable demand. The fact that no such increase occurred further suggests a shift outward in the demand for skilled workers.

C. Labor Demand Estimation

The second method for demonstrating change in demand is to estimate labor demand functions for manufacturing production employment by skill group. Most of the necessary data are available in the U.S. Bureau of the Census' May Current Population Survey (CPS), which provides annual data on individuals' occupation, industry and average hourly earnings. Each month, roughly 60,000 individuals are surveyed by the CPS, and from this survey weights are derived which allow the responses to be scaled-up to population levels. The May survey is the only one in which respondents are asked to report the wages on their current job. A panel of occupational employment and wage data by industry was constructed using the May CPS tapes for the thirteen years from 1973 to 1985. The sample used below excludes the self-employed, those reporting zero hours worked or zero wages on the current job, and those less than sixteen or more than sixty-five years of age. Workers who worked less than thirty-four hours per week, and hence are considered part-time, were included in the sample. However, part-time work is uncommon among manufacturing production workers. Throughout the period, their share is roughly two percent of total employment in skilled production employment and five percent in unskilled. There is no significant upward trend over the period.

The CPS provides data on individuals. From this base data mean employment shares and wage ratios were calculated for three aggregate occupational groups in each of twenty two-digit SIC manufacturing industries annually for 1973-1985.[32] Each observation in the transformed data is, therefore, an occupation, by industry, by year cell. The three occupational groups used are skilled production workers (craftsmen, foremen and kindred workers), unskilled production workers (operatives and laborers) and white collar workers (managers, professional and technical, clerical and sales). These occupational groupings are a first cut at the data and they rely on the efficacy of Census definitions as to which occupations belong in which group. They also assume no increase in skill within occupations. A more detailed analysis would begin with individual occupations and aggregate, either as was done with the O.E.S. data, or according to some other algorithm which distinguishes among occupations on the basis of their likely role in flexible production. The problem with the more detailed approach is the very small sample sizes for individual occupations, particularly after 1978. Finally, there is a substantive

[32]The fundamental problem with the CPS data is that after breaking the observations along twenty industry and three occupational group lines, the cells are often quite small. In particular, beginning in 1979 only one-quarter of the respondents were asked to report their wages, so the problem is more severe from 1979 to 1985 and the occupational employment and wage estimates are subject to substantial sampling error. In some small industries in the post-1978 sample, only a handful of individuals are sampled in one or more of the three occupational groups.

occupational redefinition in 1983, which makes the share levels non-comparable across the periods 1973-82 and 1983-85.

The mean employment shares and relative wages for skilled and unskilled production workers in all industries are shown in Table 6, and they support the results given earlier from other sources. The share of skilled production workers rises from 1973 to 1982, and continues to rise in the new definitional structure as well. Relative wages are quite stable throughout the period: they vary between a range of only 1.25 to 1.35 with standard deviation of only .026. Thus these data, too, support the case for a shift in labor demand.

Equation (3) suggests that labor demand for skilled and unskilled workers depends on wages, product life-cycles and training costs. Unfortunately, product life-cycles and training cost data do not exist for most industries. Hence, an alternative is pursued. Labor demand functions are estimated with time trends included to proxy for shortened product life-cycles over the sample period. Since we are primarily interested in the employment shares of skilled workers rather than their employment level, the dependent variable is the share of skilled workers in total production employment. Accordingly, wages enter as ratios. The unemployment rate is included because skilled workers are less likely than unskilled workers to be disemployed in downturns: skilled workers tend to have higher seniority, and can better perform several jobs when demand is low. The estimating equation, therefore, is:

$$(S/P)_{it} = \alpha + \beta_1(\text{time})_t + \beta_2(\text{newdef})_t + \beta_3 \ln(w_s/w_m)_{it} + \beta_4 \ln(w_s/w_u)_{it} + \beta_5(\text{UR})_t + \beta_6 \ln(\text{KS})_{it} + \sum \gamma_i(\text{IND DUM})_i + \epsilon \quad (5)$$

where:

S = skilled employment;
P = total production employment;
time = time trend;
newdef = dummy for change in occupational definitions; = 1 for 1983-85;
w_s = product wage of skilled production workers;
w_m = product wage of white collar workers;
w_u = product wage of unskilled production workers;
UR = civilian unemployment rate;
KS = constant dollar capital stock per production worker, by industry, equipment and structures;
IND DUM = industry dummies.
i = two-digit SIC industries
t = year

Since the dependent variable in (5) is an employment share, the expected signs of the coefficients require a little exposition.[33] First, the coefficient of primary interest is β_1, and our model suggests $\beta_1 > 0$. The nature of the occupational redefinition implies $\beta_2 < 0$. We have argued that β_5 should be > 0, and to the extent that skilled and unskilled production workers are substitutes, we expect $\beta_4 < 0$. The signs of β_3 and β_6 are ambiguous ex ante, since they depend on the degree of substitutability among the inputs. Previous results on capital-skill complementarity (Brendt and Christianson (1973)) were based only on a white collar versus blue collar distinction. Complementarity between skilled production workers and capital would imply $\beta_6 > 0$.

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[33]It is worth emphasizing here that this endeavor is not intended primarily to recover parameters of the production function. Rather, its goal is to look for a shift in demand, controlling for other factors likely to influence S/P.

Estimation of (5) requires variables that shift supply to serve as instruments for the industry/occupation wages. Not surprisingly, it is very difficult to find good instruments. Characteristics of the workers employed are invalid, since they are a function of demand. Even lagged industry output is likely to be endogenous if shocks to output are serially correlated. Consequently, several variables measuring educational attainment in the workforce over time are used as instruments. Specifically, the instruments are three variables measuring the annual share of employed persons whose educational attainment is 7 years or less, 8 - 11 years, and 12 -15 years.[34] While these variables are exogenous, they have no cross-sectional variation and are not highly correlated with the wages. Therefore, (5) is also estimated using OLS. It should be stressed that the OLS estimates are merely partial correlations and have no structural interpretation.

Table 7 shows the results from estimation of (5), using various specifications and estimation methods. Column 1 gives the OLS estimates of S/P regressed on the time trend, newdef, and UR, using only the time series observations derived by aggregating across industries. The coefficient on time is of reasonable magnitude - S/P rises by roughly five percentage points over the 13 year period - and statistically significant. The unemployment rate, too, has the expected sign and is statistically significant, suggesting that the share of skilled production workers does

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[34]The source for these data are annual issues of Educational Attainment in the United States, published in the U.S. Bureau of the Census' Current Population Reports series.

rise in downturns. In this and all subsequent specifications, experiments were performed by splitting the time trend after 1982, and by interacting it with UR to test for particular cyclical sensitivity to the 1982 downturn. The results were negative: the positive time trend remains significant.

Column 2 reports results from the full panel. In order to adjust for the relative size of each industry, the data are weighted by the square root of production employment. If the error term in the regression is a function of the size of the industry, as is the case in this sample, OLS is inefficient due to heteroskedasticity. Weighting by the square root of production employment reduces the heteroskedasticity and yields more efficient estimates. The results are, not surprisingly, essentially identical to those in column 1.

Column 3 reports the instrumental variable estimates of (5).[35] The estimated coefficients support the model. The share of skilled workers did increase with time, after controlling for other factors, as evidenced by the positive and significant estimate of β_1. The point estimate for β_4, the coefficient on the ratio of skilled to unskilled production worker wages, is negative, as predicted by the model. The point estimate for β_3 is positive, which suggests complementarity between white-collar and skilled production employment. However, the estimated coefficients on

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[35]These and all subsequent results are generated from weighting the data as described above in the text. We experimented with inclusion of the real price of raw materials, but it was never significant and had no effect on the other estimated coefficients.

both relative wage variables are not significant. The large standard errors result primarily from the poor fit in the first stage regression. The educational attainment instruments have no cross-sectional variance, and simply are not tightly correlated with the wages. Thus, while the point estimates for β_3 and β_4 are consistent, they are rather imprecise. Finally, capital stock per worker has a positive coefficient, as predicted, significant at the 10% level.[36] The unemployment rate has no significant effect. Column 4 reports a more parsimonious specification. The results are very similar to those in column 3. The stability of the estimated coefficient on the time trend across columns 1-4 is striking: adjusting for wages and the capital stock has no effect on the estimated shift over time to skilled workers.

Columns 5 and 6 present OLS estimates. The likely presence of simultaneity bias is evidenced by the fact that the estimated coefficient for β_4 changes sign. These results, which are simply partial correlations, yield almost identical estimates for β_1.

In sum, this section has shown that labor demand for manufacturing production workers has shifted in favor of skilled workers since 1973. This result is robust to a variety of specifications and estimation techniques, and is consistent with the employment share and relative wage findings presented in previous sections. The next section reviews results from related studies on labor demand by skill group.

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[36] See Chapter IV for results on the inclusions of investment rather than capital stocks.

D. Related Work on Shifts in Labor Demand by Skill Group

While no other studies examine the skill composition of labor demand for manufacturing production workers, several papers do examine shifts in labor demand more generally. In an important study of the complementarity between technological change and skill, Welch (1970) argues that skill influences output in two ways: directly as a factor of production, and indirectly by enhancing the allocative efficiency of the other inputs. Welch contends that technical change is non-neutral across skill groups, and tends to raise disproportionately the productivity of more highly skilled workers:

> If educated persons are more adept at critically evaluating new and reportedly improved input varieties, if they can distinguish more quickly between the systemic and random elements of productivity responses, then in a dynamical context educated persons will be more productive. Furthermore, the extent of the productivity differentials between skill levels will be directly related to the rate of flow of new inputs. (p. 47)

Welch's empirical work is restricted to a 1959 cross-section of agricultural workers. He estimates an equation in which factor shares and measures of nonlabor inputs and research expenditures are explanatory variables for the relative wages of college versus less educated workers. The results support Welch's hypothesis that research expenditures -- a proxy for technological change -- increases the relative wages of college educated workers, after controlling for factor shares. Welsh argues that the rate of change in technology, not the level, is critical:

> If production were to become technically static, eventually the productive characteristics of all inputs would become fairly well understood. Under such conditions it is difficult to understand how

education could enhance allocative efficiency. (p. 53)

In more recent work, Bartel and Lichtenberg (1987) explore the issue of whether more highly educated workers have an advantage -- are more productive -- at implementing new technology. They argue that in production environments experiencing rapid technological change there is an abnormally high degree of uncertainty as to what constitutes effective task performance, and rather extensive learning is required on the part of the workers. Bartel and Lichtenberg test this claim by using plant-level data for manufacturers to estimate a cost share equation for highly educated (>12 years education) workers. They employ several measures of technological change, including the age of the capital stock and the amount of research and development expenditures. They find that the cost share for highly educated workers is indeed a decreasing function of the amount of experience with a technology; highly educated workers do have an advantage when the production environment is characterized by rapid technological change.

While these results do not speak directly to the issue of flexible production and skilled workers, they are clearly consistent with our theory. If flexible production is also, as we have argued, characterized by chronic change in the tasks performed by workers and extensive learning requirements, then the implications are similar in both cases.[37] What is central in all three models is the need for workers to learn and adapt,

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[37]If Bartel and Lichtenberg's technological change measures are positively correlated with reductions in product life cycles, then their empirical results are supportive of our model.

whether it be due to technological change, alterations in the product mix, reorganization of work, or all three.

Since research began on this thesis, there has been a flurry of activity examining changes in the structure of relative wages by education and demographic groups. It is important to point out at the beginning that this work, discussed below, focuses on groups, such as college graduates and non-manufacturing workers, that are not the main focus of the empirical work in this thesis. Recall that the methodology of the thesis was chosen to restrict the sample to manufacturing production workers specifically because the restricted sample generates a more powerful test for the central hypothesis of a shift in production regimes. As is shown below, this hypothesis remains as an important explanation for the unresolved findings from the recent work on the broader sample.

The most comprehensive recent work is Murphy and Welch's (1988a) analysis of changes in relative wages across educational groups. Murphy and Welch construct age/education cells annually from 1964 - 1986 from the March CPS and estimate age-earnings profiles for several education groups. They find that after years of decline, the relative return to education rose enormously from 1979 to 1985, as the wages of college graduates rose substantially relative to those with less education. Chart 4, a reproduction of a portion of Figure 2 from Murphy and Welch (1988b), shows the time series of relative wages for college and high school graduates, with two different experience cohorts. The post-1979 increase is striking, as the increase more than offsets the declines of the previous decade.

Murphy and Welch (1988a) show that the increased relative return to education is not consistent with stable demand. Indeed, since average educational attainment was rising, stable demand would have implied smaller education wage differentials. They argue that a demand-based model in which changes in international trade influence sectoral employment patterns is consistent with the observed pattern of relative wages. In a subsequent paper, Murphy and Welch (1988b) calculate comparable relative wage profiles by race and gender. The more disaggregated results are then compared with employment distributions of like groups by sector to see whether international trade-induced compositional demand shifts translate into changes in relative wages that agree with the observed patterns. For example, white women with less than 16 years education are far more likely than their male counterparts to be in sectors other than durable goods; the sector hardest hit by the trade deficit. This is consistent with the sharp rise in the relative wages of women versus men since 1979 in this educational group.

The Murphy and Welch story is purely compositional: the shift in relative demand comes entirely from changes in employment shares across sectors. While the growth of international competition is important to our story, Murphy and Welch do not consider within-industry changes, which are the crux of our story. However, Table 8, reproduced from Murphy's March 1989 NBER Fluctuations Conference remarks, shows that even in their data most of the relative wage changes from 1979-86 are within two-digit industries. In particular, for males with less than 16 years education, the vast majority of the relative decline is within industries.[38]

The importance of within-industry changes has now been confirmed by other studies. Blackburn, Bloom and Freeman (1989) examine competing explanations for the "conjunction of falling relative/real earnings and declining use of less skilled labor" (p. 8); i.e. the shift in relative labor demand away from less skilled workers. Using a variety of techniques, earnings measures, and education and occupational groups, they conclude that roughly one-third of the decrease in relative earnings of the less skilled from 1973 to 1987 was due to movement across industries or other industry-related factors.

Next, the authors calculate the within-industry changes and regress them on what are described as industry characteristics: the percentage of females with various educational levels; the percentage of men less than 35; and the percent of the workforce that is unionized. They find that only the unionization rate is a significant determinant of the within-industry changes, and conclude that the results do not support within-industry explanations. But in fact, what their results really show is that the three explanatory variables they have chosen do not explain much of the within-industry variance. The unexplained within-industry variance

[38]Recent work by Katz and Ravenga (1989) on Japan, which has a large trade surplus in durables, also shows a demand shift toward more highly educated workers, but the magnitude is lower than for the US. These results also suggest that something more is going on. Future work by Katz and Loveman will explore these issues in the United Kingdom, France and Germany.

remains critical to the observed changes in relative wages.

Finally, Blackburn, Bloom and Freeman calculate estimates of the impact of de-unionization and the declining real minimum wage. They conclude that these two factors together account for roughly another third of the total decline in the relative earnings of the less skilled, leaving another third unexplained. However, a major problem with this latter calculation is that it does not explain why, despite the sharp reductions in the relative wages resulting from de-unionization and the declining real minimum wage, relative employment of the less skilled also fell. It is precisely the poor employment prospects of the low skilled that is the focus of this thesis, so these results only further emphasize the need for explanations that can account for the co-movement of wages and employment of the low skilled.

Moreover, while noting that unionism was an important boost to the wages of less skilled blue-collar workers, the authors do not address the causes of the decline in unionization that, in turn, affect wage differentials.[39] It is quite possible that at least part of the decline in unionization is related to the fact that industrial unionism was developed to meet the needs of mass production. If the organization of production is changing and unions are not themselves changing in order to be attractive to workers and palatable to managers, then the two phenomena may be closely related. In any case, the Blackburn, Bloom and Freeman

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[39]Freeman has, of course, discussed the reasons for the decline of unionism elsewhere, and the issue is by no means resolved.

study leaves unexplained a great deal of the changes in the relative wage structure.

Bound and Johnson (1989) conduct a similar examination of changes in the relative wage structure from 1979 to 1987. In their consideration of the international trade argument of Murphy and Welch, Bound and Johnson correctly point out that in order to have generated the observed changes in relative wages, shifts in product demand must have been large enough to more than offset the large demographic shift which increased the supply of more educated workers (and, ceteris paribus, would have lowered the relative earnings of the higher educated groups). They find that shifts in product demand, "do not come close to overwhelming the perverse supply changes that occurred during the 1980s. ... Further, the demand shifts observed during the 1980s are only a slight acceleration of the trends of the 1970s." (pp. 25, 32)

Bound and Johnson also examine changes in the incidence (across industries) and average level of rents as sources of changes in relative wages. The results are positive but small, due largely to the fact that the observed wage changes are dominated by group rather than industry-specific effects.

Bound and Johnson conclude that technological change is a:

> Candidate to account for the major changes in the wage structure. There is a great deal of anecdotal evidence that production processes have changed significantly over the past decade in a manner that favors more relative to less educated workers.... It is somewhat unsatisfactory to conclude that the principal cause of the major phenomena we sought to

> explain was due to factors we cannot observe in our data set. Further, it is difficult to conceive of ways that the technological change hypothesis can be tested directly even with an ideal data set. ... If technological change is the correct explanation, however, we would expect that educational differentials will not decline as the foreign trade deficit shrinks in the 1990s. (pp. 33-34)

These studies of the U.S. wage structure have been discussed at some length because they identify, but fail to explain, shifts in labor demand consistent with those documented in this thesis. The connection is far from complete: the samples are different as are the groupings whose labor demand is at issue. The differences are, however, for two good reasons. First, quite coincidentally, the ideas that motivate this thesis were conceived well before the published debate on the wage structure. Second, and much more importantly, the empirical tests in this thesis were designed to bring maximum power to bear on the hypothesis of a change in the organization of production, a within-industry phenomenon. They purposefully exclude the across-industry and white-collar/blue-collar dimensions that complicate the wage structure research. The results from this thesis suggest that at least a portion of the mysterious within-industry shift in labor demand may be due to changes in the organization of production favoring more highly skilled workers. If the results from the production workers only are correct, the overall shift in the skill structure, including white-collar jobs, is even more substantial (as the figures in Table 5 indicate). As was the case with Bound and Johnson, the fundamental sources of the changes in the organization of production are not observable. But the supporting evidence in this thesis goes a long way toward identifying changes in the organization of production as an important cause of the observed shifts in labor demand.

CHAPTER III

CHANGES IN THE ORGANIZATION OF PRODUCTION IN GERMANY AND THE UNITED KINGDOM: A COMPARATIVE ANALYSIS

The preceding chapter showed that there has indeed been a shift in relative labor demand favoring skilled production workers in the U.S. While this result supports the hypothesis of a change from mass to flexible production, it does not preclude other explanations. Increased competition and volatility in product markets since the early 1970s has by no means been purely an American phenomenon. Other industrialized countries have also been affected by increased product market competition, increased variance in input prices, and heightened consumer demand for specialized products. Therefore, if the hypothesis of a change in the organization of production is correct, these similar stimuli should have yielded a shift in relative labor demand in other countries as well. Historical and institutional differences across countries influence the degree to which production regimes change, since these differences establish initial conditions and affect adjustment mechanisms in each country. But other factors, such as technology, can be effectively held constant by looking cross-sectionally at advanced industrialized countries such as Germany and the U.K.

This chapter uses cross-country variance in institutional structures to generate additional testable implications of a change in the organization of production. In particular, vocational training systems vary enormously across countries. Since training systems determine the supply and, to a great extent, the relative cost of skilled workers, cross-country differences in vocational training systems affect significantly the organization of production and the skill composition of employment. In the context of the model in Chapter I, the greater availability of highly skilled workers will generate a larger steady-state ($q_t = q$) share of skilled workers. In other words, the organization of production is a function of the supply of skilled workers, as determined by the training system.[40] Furthermore, while the model did not consider supply constraints explicitly, more pervasive training reduces the likelihood that a shift to skilled workers stimulated by reductions in product life-cycles will be impeded by sharply increased relative wages or simply inadequate supply. Hence, a training system that fails to provide skilled production workers can both militate in favor of a mass production orientation and impede its transformation.

This chapter first documents the significant differences in vocational training between Germany and the U.K. It then draws on these differences to test hypotheses about how the organization of production and skill composition of employment would vary across the two countries. The main prediction of the analysis is that Germany should have had a

[40]Of course, the organization of production may also influence the training system.

larger share of highly skilled workers at any given point in time as a consequence of its training system. The U.K., on the other hand, has a training system less conducive to flexible production. Indeed, skilled craftsmen are sufficiently scarce, and their job demarcations sufficiently rigid, as to make flexible production difficult. Nonetheless, the stimuli to flexible production common to industrialized countries in recent years should have caused an increase in the share of skilled manufacturing production workers in both countries. Data from Germany and the U.K. support this prediction, and the dispersion in the level and changes in employment shares by skill group suggest that factors other than simply technological change determine the skill composition of employment.

A. Vocational Training

This section provides a brief overview of the vocational training (VT) systems in Germany and the U.K. The German VT system is extremely well suited to flexible production, because it provides workers with a combination of practical skills learned on-the-job with theoretical skills learned in the classroom. German youth complete compulsory full-time schooling at age 15. Those who do not continue full-time education must, for the next three years, attend, one day per week, a vocational school associated with their job. In the case of industrial craft apprentices--the VT group of main interest to this thesis--eligible employers have discretion over the details of the practical training, subject to general requirements stipulated in the Federal regulations for each trade. Industrial craft apprentices may only be employed in shops having a

"Meister"--a craftsman of the same trade who has completed advanced instructor training--to serve as the apprentice's supervisor. At the end of the training period the worker takes formal examinations covering both practical and theoretical knowledge. The examinations are standardized nationally and are drafted and accredited by the Chambers of Industry and Commerce. This dual system of practical and formal training is administered by the federal Ministry of Vocational Training, with the support of the employer's associations and trade unions. Together these three groups determine the number of apprenticeships in each craft and structure the curriculum. The current VT system has its origins in the medieval guild system, and has functioned essentially unchanged for at least sixty years.

The German craftsmen, having completed an apprenticeship, offer a wide range of skills. The dual structure of the apprenticeship ensures a mix of practical experience and general knowledge that is exceedingly well-suited to an organization of production in which workers are required to perform a wide and varying range of tasks. Industrial relations in Germany feature a system of collaborative institutions between labor and management that facilitate very wide job classifications. Work is organized such that craftsmen perform a broad spectrum of tasks that take advantage of their training.

The contrast with the U.K. is quite stark. The failure of VT is one of the most often cited culprits in the demise of British manufacturing; an allegation which is bolstered by a comparison with

Germany. British youth are not compelled to attend school past age 16. Upon completion of compulsory education, youth may enter apprenticeship training, which looks, at least superficially, much like German apprenticeships. The Industrial Training Act of 1964 established Industrial Training Boards, staffed by union, government, and employer representatives, to oversee training in each industry. In some cases formal classroom training and successful completion of examinations are required. But, in general, an apprentice is required only to "serve his time," a period of roughly three years, and on-the-job supervisors need only have attended a several-day briefing course. Apprentices in many crafts do take examinations set by the City and Guilds of London Institute, but the exams cover only the theoretical portion of the craft skills. On the basis of extensive comparative analysis, Prais (1986) concludes:

> It seems likely that the majority (of British apprentices) have not passed any written examination, and only a small proportion have undergone a series of tests comparable to those in Germany (p. 181).
>
> So long as technologies and markets were stable, a practical training of the kind offered by the traditional British apprenticeships may have been adequate. But when technology advances rapidly, and production methods change and require familiarity with a broader spectrum of technologies, it is to be expected that the grounding in general principles provided by the German methods of training yields a craftsman both more capable of and more interested in adopting progressive methods (p. 183).

In sum, VT for the best British apprentices--those who take examinations in challenging crafts--is roughly equal to that in Germany. But for middle and lower level trainees the difference is quite substantial. Furthermore, in most cases union rules prevent wage differentials on the basis of examinations or further study. Hence, as

Prais (1981a) argues, the British system is stuck between no compulsory training and weak private incentives for training.

The result of this dilemma is evident in comparisons of quantities of skilled workers between Germany and the U.K. Table 9 shows vocational qualifications of workers in manufacturing industries in the U.K. (1974-78) and Germany (1978). The "intermediate" group is made up almost entirely of craftsmen and apprentices. The differences between the U.K. and Germany are enormous: in essentially every industry, the employment share of the intermediate group in Germany is twice or more that of the U.K. The difference is reflected in the "none" category, which in the U.K. consists of those with no educational or vocational qualification and in Germany consists of those who failed, or did not take, their vocational certification exam. Prais (1981b) argues that the qualification categories are roughly comparable across the two countries, so the figures in Table 9 reflect the true magnitude of the training gap. Moreover, the current flows will only maintain or worsen the situation. Table 10 shows recent awards of craft qualifications in Germany and the U.K. Despite roughly equal total employment in manufacturing, Germany produced 2.4 times as many craftsmen, and their average training level was higher. Indeed, the output of British VT has declined substantially in recent years. The share of apprentices in training fell from 2.2 percent of manufacturing employment in 1982 to 1.1 percent in 1987.[41]

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[41] Employment Gazette, U.K. Department of Employment, Table 1.14, various issues.

A recent issue of the Oxford Review of Economic Policy was devoted to British VT and its poor standing vis-a-vis other OECD members. In their contribution to this issue, Finegold and Soskice (1988) show that whereas more than 85 percent of sixteen year-olds in the US, Canada, Sweden, Japan, and Germany are in full-time education, a majority of English students leave full-time education at age sixteen. Furthermore, British employers not only do not make up the training shortfall, but rather exacerbate it by spending much less on training than in other industrialized countries.[42] Finegold and Soskice argue that Britain is locked into a low skill-low quality industrial organization in which poor training leads to an organization of work and choice of final product based on routinized, low skill jobs, which themselves discourage further training. Wage structures which depend on seniority rather than skill (unlike Germany, where the reverse is true) reinforce this outcome. Quoting Tipton (1982), the authors conclude: "The key to improving the quality of training is the design of work and a much needed spur to the movement for the redesign of work...may lie in training policies and practice" (p 28).

B. Changes in Relative Labor Demand in Germany and the U.K.

The comparison of training institutions suggests that, on the basis of the model presented in this thesis, the employment share of skilled manufacturing production workers should have been higher in Germany for

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[42]British firms are estimated to spend .15 percent of turnover on training, while the equivalent figure is 1-2 percent in Japan, France, and Germany.

many years, and there should have been a shift in favor of skilled workers in recent years in both countries. If the VT training system was a serious impediment in the U.K., as seems likely, the shift should have occurred later and more slowly in the U.K.

<u>Germany</u>

The German national statistical office surveys manufacturing establishments quarterly and reports employment shares for three production worker skill groups. The survey is a representative sample of approximately twelve percent of all manufacturing establishments with ten or more employees. The highest skill group includes jobs requiring formal apprenticeship or equivalent training, while the intermediate group includes jobs requiring less than that level but more than six months of training. The lowest skill group is for jobs needing less than six months training. (Note that only group 1 would be counted in the intermediate category of Table 9.) With respect to the U.S. classification used in Table 3, the highest German skill group requires more training -- three years versus two -- than does the skilled group for the U.S. The average training requirement is also higher for the intermediate German classification. Finally, it is important to point out the establishments with fewer than ten employees tend to have larger than average shares of the highest skill groups. These small firms belong to the "Handwerk" sector, which consists largely of maintenance and repair firms operated by craftsmen. The exclusion of this group therefore understates the size of the skilled worker employment share in the following discussion.

Unfortunately, wage data consistent with the employment shares are not available at this time. Consequently the results that follow cannot be interpreted as changes in labor demand. Efforts undertaken to obtain unpublished data from the Germany Federal Employment Institute in Nurnberg will hopefully bear fruit in future work.

Table 11 reports the employment shares from 1960-1987 for three of the four durables industries used earlier for the U.S. Data were also provided for the vehicles industry, but the time series included unexplained breaks in the early 1980s and was therefore not included. Three facts stand out in these statistics. To begin with, the share of the highest skilled group has risen substantially over the period. Second, the timing of this shift shows that much of it occurred rather early, between 1960 and 1978. For example, the share of highly skilled machinery workers rose six percentage points from 1960 to 1978. The detailed U.S. data begins in 1977, so comparisons are difficult to make, but it seems unlikely that such a large shift began so early in the U.S. Finally, a very large portion of German production workers are highly skilled. This is no doubt largely a consequence of the supply effects from the VT system, but it nonetheless certainly influences the organization of production. Given the more stringent definition of skilled worker in the German classifications, it is clear that Germany has a much larger share of skilled production workers in these industries than does the U.S.

U.K.

Table 12 gives employment shares by skill groups for production workers in selected manufacturing industries in the U.K. These data come from establishment surveys conducted prior to 1980 by the Department of Employment and subsequently by the Engineering Industry Training Board (EITB). Questionnaires are sent to all establishments with 1000 or more workers, and to a sample of establishments with 11-999 workers. In 1980 data was collected from 7.9 percent of all establishments, covering 44.6 percent of all employees. The observed discontinuity in shares at the time of the switch to the EITB (1979 to 1980) is largely the result of the EITB not extrapolating its results from the 11-99 worker size group to the non-sampled 1-10 size group (a group with a higher than average share of skilled workers), minor changes in coverage within industries, and the replacement of a fixed sample with a new sample. In any case, the data in Table 12 are non-comparable across 1979-80. Time series data are available only for five industries: those shown in Table 12, marine engineering and metal goods not elsewhere classified. The latter two were not pursued because of the very small size of marine engineering and the residual nature of metal goods not elsewhere classified.

Two points stand out in the time series of employment shares in Table 12. First, the shares were remarkably stable in mechanical engineering and vehicles during the 1970s. Second, the share of skilled production workers rose significantly after 1980. Thus, the pattern of movement in employment shares predicted in the preceding discussion obtains in mechanical engineering and vehicles. The shift to skilled workers indeed happened, but it took place much later in the U.K. than in Germany, and a little later than in the US. The definition of a skilled production worker in these data--a craftsman in an occupation entered through apprenticeship or equivalent training--corresponds with the most highly skilled group of German production workers (with the caveats noted in the preceding discussion). A comparison of the levels of skilled workers is complicated by the break in the U.K. data in 1980, but nonetheless in the machinery and electrical machinery industries --the only two for which comparison is possible--the German share is unambiguously higher. Finally, note that electrical engineering again has a small share of skilled workers in the U.K., but their share rose by four percentage points from 1973 to 1979 and a bit more thereafter.

Wage data are needed to demonstrate a shift in relative labor demand in the U.K. Wages by occupation and industry are very difficult to find, particularly with sample sizes sufficient to yield precise averages. I began with the General Household Survey (GHS) of the U.K., an annual U.K. version of the U.S. Current Population Survey. The GHS does provide wage data by occupation and industry based on interviews with 30,000 individuals annually since at least the early 1970s. The problem is that once the sample is limited to those at work in manufacturing production occupations, the cell sizes are very small and the average wages are exceedingly imprecise.

More comprehensive data are available from establishment surveys published by the Department of Employment. Table 13 shows relative wages for male production workers in three industry groups (the only ones for which the data were collected). Engineering is an omnibus industry grouping that includes mechanical engineering, electrical engineering, shipbuilding, vehicles and metal goods n.e.c., and in 1980 employed more than one third of total manufacturing. Shipbuilding is a very small industry, employing only roughly two percent of total manufacturing employment in 1980. These data have the advantage of being comparable in terms of occupational definitions with those in Table 12, but the survey was discontinued after 1980. Since males constitute the overwhelming majority of production worker jobs, the exclusion of women is not a significant problem.

The relative wages of skilled workers changed very little from 1974 to 1980. In engineering, relative wages of skilled versus semi-skilled workers varied little until 1979, when they rose roughly three percent. After a drop in 1975, the ratio of skilled to unskilled wages was essentially constant. Relative wages in shipbuilding moved very little despite large employment losses, and relative wages in chemicals also were stable. Taken together with the employment share data, the evidence suggests very little movement in relative labor demand over this period.

A more comprehensive source of wage data is the New Earnings Survey (NES). Conducted annually in the spring, the NES is a survey of roughly 120,000 people that is conducted through the individual's employer. Names are selected randomly from the national insurance contribution records, and matched to employers. Forms are then sent to employers for completion. Each year approximately two-thirds of the sample is retained to form a matched sample with the preceding year. The advantage of the NES is its large sample size, but the cost comes in its imprecise occupational groupings. The British occupational grouping system separates manual from non-manual, but within the manual category the occupations are grouped very broadly by function. A complete list of occupations is given in Appendix A, but here only three groups are used:

group 14: Processing, making, repairing, and related (metal and electrical)

group 15: Painting, repetitive assembling, product inspecting, packaging, and related

group 17: Transport operating, materials moving, and storing and related.

These three groups are the main manual occupational groups in manufacturing. While skilled occupations exist in each of the three groups (e.g., foremen), group 14 is made up mostly of skilled workers while the latter two are not. Data are available separately for one individual occupation--repetitive assembling--which is a semi-skilled job. NES data with comparable occupational groupings are available annually from 1976.[43] Sample sizes are very small for women, so the analysis is

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[43]Adjustments were made for the change in SICs in 1980.

limited to men. While the shares of women did rise in these occupations, they were always quite small.

Table 14 reports the NES wage and employment data for 1976, 1979, 1985, and 1987. These years were chosen to include only years when the British economy was relatively healthy, and thereby insulate the results from major cyclical effects. Chart 5 plots the growth rate of real Gross Domestic Product in the U.K. from 1972 to 1987. Note that 1976, 1979, 1985, and 1987 are all years of relative prosperity. Mechanical and electrical engineering and vehicles were chosen for comparability with the employment share data in Table 12. Despite macroeconomic growth, employment in each of these three large durable manufacturing industries declined significantly over the period. Finally, the data on relative wages are ratios of group medians. While the standard error on group averages were small--less than two percent--there were a few cases where averages were not reported. The medians are, in any case, very close to the averages. A typical sample size, say, for group 14 in mechanical engineering or vehicles, was roughly 1600.

The relative wage data in Table 14 show little movement overall. There are a few exceptions, such as a steady increase for 14/15.1 in electrical engineering and a sharp drop for 14/17 from 1976 to 1979 in mechanical engineering. The lack of major changes is not surprising given the central role of egalitarian wage structures in British industrial relations.[44] However, as in the U.S., the critical finding is that

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[44]See Prais (1981b).

skilled workers did not get any cheaper, which is sufficient to show that relative labor demand must have shifted in favor of skilled workers in order to generate the joint outcome of higher employment shares and stable or slightly increased relative wages. Indeed, while the labor force in the U.K. did grow over the period, the number of craftsmen declined as apprenticeships fell significantly. Therefore, there is little evidence of any increase in the supply of skilled workers.

The employment data in Table 14 are derived by simply taking the ratio of the sample sizes for each group. The NES does not report sample weights, but the initial sample was random, and thus self-weighting. The use of significant (two-thirds) matched samples over time is not a problem for our purposes so long as those already employed in any given year have the same probability of holding a given job as do those just entering employment (the matching effectively overweights those already employed, although they needn't hold the same job since the inclusion in the sample is based on simply being employed). In the U.K., production labor markets are occupationally based and jobs are tied to a great extent to training rather than seniority, much more so than in France or the U.S. Therefore, longer tenure is less likely to push workers into more highly skilled jobs and the bias in the NES matched data is not likely to be large.

The employment ratios show more movement than the relative wages. The general pattern is for the ratios to drop a little from 1976 to 1979 when total employment was stable, and to rise from 1979 to 1985 when employment fell.[45] There is little change after 1985. Thus this evidence confirms the employment share results from Table 12, and additionally suggests that the major crisis hitting British manufacturing after 1979 was the stimulus to changes in the organization of production. The last section of this chapter explores this point in the British vehicle industry, and presents a case study from Germany that illustrates the comparative results from Germany and the US.

C. Case Studies

1. The Car Industry in Britain

Employment in the British vehicles industry fell by more than forty percent from a peak of 485,000 in 1978 to under 300,000 in 1983. Marsden et. al., (1985) provide detailed occupational data for the industry, which are shown in Tables 15 and 16. Table 15 provides more detailed occupational data from the 1971 and 1981 population censuses. Marsden, et. al., argue that, because other data show little change prior to 1979, most of the observed changes took place from 1979 to 1981. Not surprisingly, managerial and technical occupations gained in employment shares, while clerical lost a bit. Among manual workers, skilled occupations (those from foreman to motor mechanics) gained while the less skilled jobs (from fitters to laborers) lost: the share of skilled jobs in total manual employment rose from 23 to 30 percent, due largely to

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[45]Employment in mechanical engineering is buoyed by rising employment in information technology equipment manufacture.

substantial declines among repetitive assemblers and laborers.

Table 16 gives more highly aggregated data from EITB surveys. In this survey the manual occupations are defined simply as craftsmen, operators and others (unskilled workers). Total employment fell by over forty percent from 1978 to 1984, and, again, it was the lower skilled manual workers who suffered the double blow of a declining share of a vastly reduced pie. Craftsmen, conversely, experienced a modest increase in employment share.

Marsden et. al. argue that the observed changes in occupational mix

> arose from the drive for increased efficiency. Major reductions have occurred in employment share for assembly workers, labourers, and clerical and secretarial staff. The assemblers have been affected partly by automation, but more substantially by changes in working practices on the line (p. 72).

The authors contend that the reorganization of production in the U.K. has been hampered by the strict job demarcations associated with craft work:

> Unlike the apprenticeship system in Germany the [British system] regulates not just the acquisition of technical competence but also access to craft work. Whereas the key to German apprenticeships and skilled work lies in access to technical competence, the pattern of regulation in Britain relies more on access to "job territories," that is sets of tasks and the use of certain tools which are the exclusive right of certain groups of workers (p. 79).

Accordingly, it has only been in the context of the crisis in the auto industry, and the need for survival, that the organization of production, and hence the occupational mix, has begun to change. In contrast to Germany, where training and the existing organization of production facilitated such changes, flexible production came late and painfully to the British motor vehicle industry.

2. Machine Tools in Germany and the US

A large body of research argues that mass production never characterized German manufacturing to the degree it did U.S. manufacturing. Loveman, Piore and Sengenberger (1987) argue that the mass production of, for example, automobiles never developed as early or as extensively in Germany as it did in the U.S. Instead, the share of employment accounted for by small firms -- the handwork sector -- remained large in Germany while it fell elsewhere. The availability of skilled labor was one critical element in this different industrial structure, but so too was the need to compete on international markets on the basis of quality and customization rather than cost. German firms did not have the large domestic markets for standardized goods available to them to the extent that American firms did, and their high labor costs prevented them from being low cost producers of commodity products. Furthermore, industry-wide collective bargaining sets binding minimum wages for all firms in an industry, which discourages mass production strategies based on low labor cost.

Herrigal (1988) presents a comparison of the machine tool industry in Germany and the U.S. that illustrates and elaborates these issues. He argues that U.S. machine tool firms established an "industrial order" based on large individual firms and a highly concentrated industry. Firms faced high volume demand from mass production industries and from the military, and produced relatively standardized products. The firms provided worker training almost entirely in-house, and consciously attempted to minimize these costs by reducing the need for skilled workers. This industrial order made U.S. firms vulnerable to the crisis of the 1980s, when the heretofore stable demand from mass production industries destabilized, and competition from abroad increased the pace of technological change. Herrigal argues:

> U.S. producers' orientation to the market in both standard and custom product areas lead them to be blinded to the important shifts in demand. U.S. producers had traditionally based the production of standardized machines on the assumption that there would be little competition in their product area. Production processes were traditionally rigid and firms eschewed customization. (p. 25)

German firms, on the other hand, historically supplied smaller, more specialized industries, and consequently never developed a strategy based on high volume and standardization. As a result, the industry was composed of small and medium-sized specialty firms, who employed predominantly highly-skilled workers. In Germany's industrial order, firms relied heavily on outside institutions; in particular, the public system for vocational education, public research institutes, cooperative banking, and a trade association. Hence, when the Germans, too, faced a crisis in the late 1970s and early 1980s, they were better able to respond than were U.S. firms because they relied on cooperation and assistance from a variety of external public and private sources.

D. Summary

The purpose of this chapter was to first identify and then exploit cross-country institutional differences to generate unique testable implications of a shift from mass to flexible production. This international comparative methodology is a powerful analytical tool, because it controls for variables, such as technology, which cannot be handled adequately when examining the U.S. alone. Predictions made on the basis of our model and fundamental differences in vocational training in Germany and the U.K. were confirmed using time series occupational wage and employment data from both countries. Finally, case studies were presented which discussed in greater detail change in the organization of production in the British auto industry and the German and U.S. machine tool industries. The next chapter develops and tests further implications of a shift from mass to flexible production using non-labor data.

CHAPTER IV

NON-LABOR TESTS FOR CHANGES IN THE ORGANIZATION OF PRODUCTION

AND

EVALUATION OF ALTERNATIVE EXPLANATIONS

Recall that the fundamental methodological problem of Chapter II was the unobservability of a key variable in the model. The results of Chapter II show that the prediction of the model is confirmed if the hypothesis of shortened product life-cycles over time is maintained. This chapter attempts to solidify the connection between product market conditions, flexible production and the shift to skilled workers. The previous chapters established that there has indeed been a shift in the composition of labor demand favoring more highly skilled workers in the U.S., Germany and the U.K. The preceding chapter used international comparative analysis to distinguish flexible production from competing explanations for the observed changes in labor demand. This chapter, too, seeks to distinguish flexible production from other possible sources of the shift in labor demand in the U.S. The first two sections are positive attempts to construct further testable implications of flexible production that are based on non-labor data. The last section considers critically other possible explanations for the shift to skilled workers.

Section A presents an industry-level proxy for unobservable product life-cycles that can be used to predict the industries in which the shift to skilled workers should be most pronounced. This proxy, the intraindustry trade (IIT) index, was first developed by Krugman (1981) in a model based on increasing returns production technology. An argument is presented in this section that IIT may also arise from changes in business strategy favoring differentiated rather than standardized goods, wherein firms are able to differentiate their product(s) such that other firms (domestic or international) cannot duplicate it. Section A begins with an elaboration on Krugman's (1981) model, and then proceeds to use data on IIT to generate a ranking of industries that can be compared with a ranking from the labor demand data in Chapter II. The results support the hypothesis that IIT has grown the most in the same industries that have experienced the largest shift to skilled workers.

Section B draws on a mix of recent theoretical work by Milgrom and Roberts (1988a,b) and case study work by Piore (1987) to develop an implication of flexible versus mass production that is testable using firm-level data. Specifically, firms using flexible production are, ceteris paribus, less likely to hold finished goods inventories, since differentiated customer demands and frequently changing products make holding inventories very costly. Mass producers of standardized goods, on the other hand, must hold inventories only for the few products they sell. Therefore, if there is a shift to flexible production, the margin between order backlogs and finished goods inventories as alternative methods for handling uncertain product demand should be moving toward order backlogs. The empirical implication of flexible production is therefore an increase in the ratio of order backlogs to finished goods inventories. The data confirm that the ratio has indeed risen, despite problems in measuring finished goods inventories accurately over time.

Section C concludes this chapter by evaluating the merits of alternative explanations for the shift to skilled workers. There are a few legitimate contenders, the main one being recent technological change. However, the evidence presented here and in previous chapters suggests that while technology played a role, the primary motivation for changes in the organization of production came from product markets.

A. Intraindustry Trade

Intraindustry trade refers to two-way trade in products of the same industry. Traditional international trade theory was based on comparative advantage inducing countries to specialize in the production and export of products for which they were the most efficient producer. The consequence is interindustry specialization with no two-way trade in similar products. Krugman's work is an effort to reconcile theory with the fact that much trade is intraindustry. Krugman's (1981) model, exceedingly elegant in its simplicity, proceeds from the assumption that consumers prefer a diversity of products and that the existence of fixed costs results in scale economies in production.

Scale economies prevent domestic competition from eliminating the need for imports, and differentiated consumer tastes ensure that a variety of products within an industry's output is preferable to one standardized product. The solution to Krugman's model shows that the extent of IIT is equal to his parameter z, which measures the similarity in factor proportions between industries (e.g. the percentage of the labor force employed in a particular industry). When z=1, countries have identical endowments. More formally,

$$I = z$$

where

$$I = 1 - [(\sum|X_k-M_k|) / (\sum(X_k-M_k))]$$

X_k = exports of industry k;

M_k = imports of industry k.

If trade is balanced in each industry -- there is extensive IIT -- I equals one. Complete industry specialization, such that each industry is only an importer or exporter, yields I equal to zero.

The striking result that the index of IIT equals the index of similarity in factor proportions fits with the fact that much IIT is between industrialized countries with fairly similar factor endowments. However, the reliance in Krugman's model on economies of scale to generate IIT, and the notion that its extent is strictly linked to factor endowments, are questionable. Krugman makes the crucial assumption that all products are producible by any firm. Hence, given free entry, only fixed costs of production prevent all goods from being produced domestically. In fact, it is precisely the desire to avoid producing something that anyone else can also produce that underlies the business strategy of flexible production. Product details, specialization to meet particular customer demands, quality and brand name identification are all sources of product differentiation that prevent any firm from copying another firm's product. Indeed, products do not simply appear. Rather, they must be developed, and firms devote enormous resources to this end. Consequently, as a particular firm introduces a series of new products, it takes other firms a significant period of time to respond.[46] For these reasons, firms are very concerned with product choice, customization to meet the needs of particular customers, and flexibility to expedite introduction of new products.

Furthermore, Krugman's (1981) model is entirely static. However, it is shown below that IIT has increased significantly in many industries since the early 1970s. Manipulations of Krugman's model would generate this result if:

a. consumer tastes changed to favor greater product differentiation
b. economies of scale in production became more prevalent
c. the index of similarity in factor proportions (z) increased.

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[46]Assuming the technology is not trivial.

While (a) is certainly plausible, (b) and (c) are substantially less so.

A much more likely cause of an increase in IIT is an increase in the prevalence of a business strategy premised on product differentiation rather than standardization. If in the U.S., and in other industrialized countries, firms are attempting to avoid standardized products where there is extreme cost competition from other countries, then a widespread shift to flexible production may be manifested in an increase in IIT.

While greater intraindustry trade (larger I) does not necessarily imply shorter product life-cycles, it is certainly consistent with shorter product life-cycles. If firms are competing on the basis of product differentiation, they are producing for small segments of the market rather than mass producing to capture the entire market. Moreover, since firms maintain rents by producing products that are not easily replicated, they have a strong incentive to innovate and increase product quality. The result is shorter product life-cycles. However, the change certainly need not be uniform across industries: ITT should have risen the most in those industries where the shift to flexible production was most acute.

As the formula for IIT indicates, IIT is calculated from imports and exports data. However, the trade data are calculated using industry classifications that differ from the SICs. The trade data come from the U.S. Bureau of the Census' <u>U.S. Commodity Exports and Imports as Related</u>

to Output. The data were aligned with the SICs and provided to me generously by John Abowd.

Table 12 shows the change in the mean intraindustry trade ratio between the two periods 1958-73 and 1974-84 for each of eighteen two-digit SIC manufacturing industries. Changes rather than levels are used because it is changes in product markets since the early 1970s that are associated with changes in the organization of production. The data show that the ratio increased in eleven of eighteen industries, and the unweighted mean change was .08. Therefore, if intraindustry trade is a valid proxy, Table 17 suggests that product life-cycles have shortened in some, but not all, industries. It is important to note that there is nothing in Krugman (1981) to predict an increase in IIT, so the fact that it rose in some but not all industries requires further explanation.

Given that product life-cycles are not observable for all industries, the flexible production hypothesis is more powerful if it is possible to predict ex ante, on the basis of observable variables, which industries are most likely to have experienced a shift to flexible production. Table 18 shows the ranking of industries in terms of their increase in intraindustry trade, and in terms of the magnitude of the shift to skilled production workers in the CPS data. The latter group was derived by running a regression for each industry of S/P on a constant, a time trend, newdef, and UR, and ranking the industries on the basis of the coefficient on time.[47] There is significant correspondence between the

[47]As was the case before, the inclusion of wage variables does not affect

two groups, particularly in the top seven: machinery, fabricated metals, transportation equipment, paper, lumber and textiles appear in the top seven of both groups. Petroleum is the only real outlier, appearing at the bottom of one list and at the top of the other. Apparently there was either a shift to skilled workers in petroleum that had nothing to do with product life-cycles, or the peculiarities of the industry make intraindustry trade a poor proxy.[48]

A more precise way to measure the predictive power of changes in the intraindustry trade ratio is to compute rank order correlations between a ranking of industries on the basis of the change in intraindustry trade and the ranking on the basis of the estimated magnitude of the shift to skilled production workers. The rank order correlation -- Spearman's correlation coefficient -- resulting from this procedure is .35, which yields a t-statistic of 1.5. Thus, while positive and fairly large in magnitude, the correlation is insufficient to reject the null hypothesis of independence between the rankings. However, exclusion of the one severe outlier -- petroleum -- results in a rank order correlation for the remaining seventeen industries of .61; the associated t-statistic of 2.98 is sufficient to reject independence.[49]

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the coefficient on time.

[48]Hirschhorn's (1984) discussion of process industries argues for higher skill requirements as a function of both more sophisticated capital and more differentiated products.

[49]If the Spearman correlation coefficient = p, then its t-stat is given by $[(n-2)^{1/2}*p] / [(1-p^2)^{1/2}]$.

The use of IIT in the context of a model of flexible production appears paradoxical, given the importance of scale economies in Krugman's (1981) model of IIT. This section has suggested, however, that scale economies are not necessary to generate IIT, and that something more is needed to understand the dynamics of IIT. Changes in the IIT ratio do seem to have considerable predictive power with respect to identifying industries most likely to experience a shift to skilled workers. To the extent that changes in the ratio proxy for changes in product life-cycles, these results provide support for a shift to flexible production by suggesting that shortened product life-cycles are responsible for the observed changes in the skill composition of employment.

B. Flexible Production, Finished Goods Inventories and Building to Order

Firms may build to order, build to stock, or both. In the case of production to order, each item is produced according to the specifications of an existing customer order. In the case of production to stock, output is produced on the basis of the firm's prediction as to what and how many products will be purchased in the future. If, as has been argued in this thesis, changes in competition and consumer tastes favor the production of specialized goods, production to stock becomes increasingly costly when goods in inventory fail to meet differentiated consumer demands. Consider, for example, the contrast between pure mass production, wherein the product is standardized, and pure flexible specialization, wherein each item is unique. In the former case, finished goods inventories are costly only with respect to carrying costs, since when demand picks-up goods can be sold out of inventory. In the latter case, inventories will not meet the specialized demands of consumers and must, hence, either be sold at discount or remain in inventory. An intermediate case may be when a firm produces many products, but the product line is stable. In this case inventories are more costly than in mass production, but less so than in flexible specialization where product demand changes rapidly. Indeed, as the degree of product differentiation increases, such that the product line is large and changing, so too does the likelihood that an inventoried good will remain unsold a given period of time. The implication is that as firms move toward flexible production they will, ceteris paribus, increase their ratio of order backlogs (OB) to finished goods inventories (FGI).

1. The Models

Support for this concept as a testable implication of changes in production regimes comes from two quite dissimilar sources. First, in a series of interviews conducted in conjunction with Piore (1987), managers in American manufacturing firms emphasized the need for more highly specialized products, closely suited to the needs of particular customers or groups. Central to that goal, they argued, is the reduction of in-process and finished goods inventories. With respect to the former, Piore argues:

> The (elimination of in-process inventories) has the advantage of increasing the ease with which production can shift from one product to another. As soon as those inventories are eliminated, attention is focussed upon the relationship among work stations in an altogether new way. In order to insure continuous production, workers are forced to relate to, and learn to understand, adjacent operations. This in turn creates an environment more conducive to flexible machinery and more generally trained labor. (pp. 4-5)

The motivation for reduction in finished goods inventories follows directly from firms' inability to maintain profitability in the sale of standardized goods. Interview respondents stated that as product mix increased, and as competitors quickened the pace of new product introductions, their firms undertook significant efforts to reduce finished goods inventories. These efforts featured both changes in production methods and improved lateral communication between marketing, manufacturing and engineering to better align production with demand.

It is the notion of communication as a substitute for inventories that motivates recent theoretical work by Milgrom and Roberts (1988 a, b). They argue that firms may respond to demand uncertainty by either using inventories (build to stock) or learning more about demand before undertaking production (build to order). Inventories are costly for the usual reasons, while learning involves costs of information acquisition. The mark-up of price over marginal cost is assumed to be an increasing function of the size of the product line, and demand for each product is random. They argue:

> The choice of the optimal product line then involves trading off the additional design and set-up costs of adding to the line against the

> resultant improved price. Moreover, a broader product line means that the market of each product actually produced is narrower, and this is costly when producing for inventory because of the lost pooling. In turn, this has implications for the relative profitability of producing to (order) or to (stock). (p. 4, 1988a)

This framework captures very well the flavor of our story. However, there is one important missing link between their model and ours: we describe the product life-cycle declining over time, given the size of the product line, as a function of competitor behavior. The Milgrom and Roberts model, instead, focuses on the relative costs of surveying potential customers versus holding inventories. Hence, there is a dynamic element missing from the Milgrom and Roberts model. Fortunately, their model includes a parameter -- the thickness of the market (number of customers) for any product given its price -- which can be varied to consider the dynamic effects of competitor behavior.

The solution to Milgrom and Robert's very complicated model (in which both the production to order versus stock decision and the size of the product line are choice variables) shows that the relative profitability of production to order increases with:

- decreases in the thickness of the market
- increases in the variability of per customer demand
- decreases in the cost of expanding the product line.

The introduction of new competitors with lower costs will reduce the thickness of the market, which favors both production to order and a wider product mix. In fact, Milgrom and Roberts (1988b) show how these are mutually reinforcing (complementary) forces.

While Milgrom and Roberts do not model labor demand explicitly, they argue that the "reduction in set-up costs achieved by flexible work rules and broadly trained employees, so that production workers do the setups rather than standing idle while specialists do this task, would lead to (flexible manufacturing)" (p. 15, 1988a). Consequently, the increased use of more highly skilled workers lowers the cost of expanding the product line in their model, and favors production to order.

In sum, the Milgrom and Roberts model is quite close to our story in spirit, is consistent with the case study evidence, and generates a simple, testable implication of flexible versus mass production: to the extent that firms are shifting to flexible production, the ratio of order backlogs to finished good inventories should rise. This is, in fact, a powerful test for a change in production regime because it rules out competing explanations for the shift to skilled workers that have no implication for the build to order versus stock decision. For example, simple international trade stories have no such implication, nor do international outsourcing hypotheses. Only a story based on pure technological change being complementary with skilled workers and favoring production to order will predict both results.[50] The next section presents the data and empirical results.

2. Empirics

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[50]An increase in the degree of uncertainty in demand for an individual product has ambiguous implications for OB/FGI.

The testable implication derived in the previous section can be stated simply: if firms were shifting from production to inventory to production to order, the ratio of order backlogs to finished good inventories at the firm level should have risen, after controlling for other variables known to affect inventory behavior. The problem in empirical implementation is inventory measurement. While order backlogs are properly valued at the sale price, inventories may be valued according to a variety of criteria each of which may yield a different dollar value for a given physical inventory. Cross-sectional differences in valuation methods are not important for this analysis, which is a time-series (or "within") exercise, but problems do arise when a firm changes its valuation method during the observation period. The accounting can be quite complex, but the essential issues can be understood with a simple example. There are two main alternative valuation methods: First In, First Out (FIFO), and Last In, First Out (LIFO).[51] A firm using FIFO must account for each item as it leaves inventory on the basis of the cost of the oldest item in inventory at the time (note: which item is actually sold is irrelevant for the accounting). In a period of inflation this method tends to understate the cost of goods sold, and, hence, overstate profits, since the item leaving inventory has a replacement cost in excess of its FIFO valuation. Not surprisingly, when inflation was high during the 1970's, many firms wished to avoid the income tax burden associated with this valuation method and switched to LIFO. Under LIFO valuation, goods leaving inventory more accurately reflect replacement cost, and the

[51]The other valuation methods are average cost, a mix of LIFO and FIFO, and replacement cost, which is much like LIFO.

inflationary boost to profits and taxes is avoided. Note, however, that these valuation methods have the opposite effect on reported inventory values: FIFO more accurately reflects the replacement cost of the reported inventory than does LIFO.

To make this counterintuitive point clear, consider two streams of identical products into inventory during four consecutive periods of ten percent inflation:

Period		Cost
1		$1
2		1.10
3		1.21
4		1.33
	Total	$4.64

Under FIFO, when one item is sold, the valuation of the remaining three items is $3.64, while under LIFO it is $3.31. A firm using LIFO may, for example, continue to value the item in inventory at $1.00 forever. The magnitude of the difference in inventory value generated by the two methods depends critically on how quickly inventory turns over. If the turnover is rapid, the difference is reduced. Nonetheless, the consequence for our purposes is that if firms shift from FIFO to LIFO during an inflationary period, it would tend to raise OB/FGI even if, in physical terms, no change had taken place. When inflation increased in the mid-1970s, many firms did switch from FIFO to LIFO in an effort to make measured profits more realistic and to reduce income taxes. For this reason, a variety of results are presented based on attempts to control for the influence of accounting methods. The results show a trend toward a rise in OB/FGI.

Compustat provides annual income and balance sheet data on all publicly-traded U.S. firms filing annual 10K reports with the Securities and Exchange Commission. Since both order backlogs and inventories are assets, they must be reported, and finished goods inventories are reported separately from raw materials and work in process. Compustat also provides a variable giving the valuation method applied to the largest share of the finished goods inventories. Firms may use several methods concurrently, but all that is known to the econometrician is the method applied to the largest share. This poses obvious problems if the split is such that more than one method is significant and the shares change over time. Efforts are made to control for this in the specification of the estimating equation.

Data were drawn from the Compustat file covering all manufacturers listed on the New York or American Stock Exchanges who were still in business in 1987.[52] The earliest year in the sample is 1970, and many firms are observed over the entire 18 years. The base sample contains 424 firms observed on average for 10.5 years. The distribution of firms by

[52]This particular sample was used mainly for convenience. Data are available also on failed firms and on firms traded over-the-counter. The large sample of firms in our sample should be representative of business practice.

two-digit SIC industries is shown in column 1 of Table 19. The sample is heavily weighted toward durables producers--81% of firms--which tend to have much larger average ratios of order backlogs to finished goods inventories.

In order to test for a secular relative increase in production to order, it is necessary to control for variables that may independently influence inventory behavior. The three most important variables in this regard are interest rates, the inflation rate, and some measure of the business cycle. The interest rate measures the nominal cost of holding inventories, while the inflation rate captures any increase in the selling price for inventoried goods. Since inventories are known to have a significant cyclical component, the unemployment rate is included to decycle the data.

The inventory valuation problems are addressed in two ways. First, the whole sample is used, including firms who change valuation methods, and two terms are added to capture the effect of the accounting changes. These two terms, one linear and the other quadratic, equal one in the year when the accounting method applied to the largest share of FGI changes, and increase yearly if the change is sustained. Many firms change methods more than once, and these variables reset after each change. Hence, the effect of accounting changes are allowed to follow an arbitrary second order process. The estimating equation is thus:

$$\ln(OB/FGI)_{it} = \alpha + \beta_1(TIME)_t + \beta_2(TBILL1)_t + \beta_3(\Delta CPI)_t + \beta_4(UR)_t +$$

$$\beta_5(\text{IVM})_{it} + \beta_6(\text{IVM})_{it} + \sum\gamma_i(\text{IND DUM})_i + \epsilon \qquad (6)$$

where:

TIME = time trend
TBILL1 = one-year Treasury Note rate
ΔCPI = annual change in CPI
UR = unemployment rate
IVM = equals one in year of accounting change and 1+n n years thereafter
IND DUM = two-digit SIC industry dummies
i = two-digit SIC industry
t = year

The other approach to handling the accounting changes is to restrict the sample in various ways, which we turn to shortly.

The first column of Table 20 shows the results of estimating equation (6) with the full sample. The central finding is that OB/FGI has increased significantly over the period, after controlling for interest rates, inflation, the business cycle and changes in accounting methods. The estimated coefficient on TIME suggests a 1.7% increase per year, which amounts to a substantial increase when sustained over ten or more years. The estimated coefficients on the interest and inflation rate variables suggest that the costs associated with carrying inventories are more tightly correlated with the inflation rate than with the interest rate. Theory, and common sense, suggest a positive coefficient on the interest rate and a negative one on the inflation rate. Instead, the results are a positive significant coefficient on inflation and no explanatory power from the interest rate. The coefficient on UR has the predicted negative sign: FGI tend to be high and OB tend to be low at the onset of downturns, and FGI run down while OB rise during upswings. However, the coefficient is estimated very imprecisely. Finally, the IVM terms are also statistically insignificant, although their point estimates show that OB/FGI did tend to rise as many firms moved from FIFO to LIFO during the inflationary mid-1970s, but at a declining rate.

Column 2 of Table 20 shows the fixed effects, or within estimates from equation (6). The data were transformed into deviations from firm-specific means, thus eliminating fixed effects which, if present, may bias the OLS estimates in column 1. The reported standard errors are adjusted for the degress of freedom lost in taking deviations from firm-specific means. The coefficient estimates in columns 1 and 2 are, however, quite close, which suggests that fixed effects are not terribly important in this case.[53] The coefficient on the time trend is smaller but still significantly positive, and the other coefficients change very little.

The remaining columns present results from various subsamples chosen to eliminate problems from changes in inventory valuation methods. The sample in column 3 excludes all observations for each firm in the years following a change in valuation methods. Hence firms are observed only up until their first accounting change, if one occurs. The results are almost identical to those in column 1.

The sample used in estimation for column 4 excludes a firm if it ever changes accounting methods. This sample is the only one which yields an insignificant time trend, although the point estimate remains large and positive. The same remark applies also to the coefficient on inflation.

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[53]Note that none of the regressors are firm specific.

The most conservative subsamples upon which to test the model are comprised of only those firms using FIFO, since there is no time series distortion in inventory valuation. The estimation results from the FIFO samples are shown in columns 5 and 6 of Table 20. Column 5 includes all years during which a firm uses FIFO, even if they are off FIFO during an intervening period. The last column includes only those years prior to the first switch in valuation methods. The results show no difference across samples in the estimated coefficient on the time trend; it is large and significant in both cases.

Table 19 shows that the industrial distribution for the FIFO subsample is very close to that of the full sample. The means of OB/FGI by industry are higher in some cases and lower in others, but the differences are small, particularly given the larger sampling error in the smaller sample. The lack of a substantial difference in the means suggests that there are not profound differences in the two groups that influenced their choice of accounting methods. Opinions from experts in this field indicate that essentially all firms with inventories could have reduced their tax burdens by switching to LIFO.[54] Therefore it is hard to see why all firms did not make the switch. The experts' speculation is that the firms that choose not to convert to LIFO might tend to be those with either rapid inventory turnover or low inventory/sales ratios (lower

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[54]The experts were Patricia O'Brien, Professor of Accounting, MIT, and Joe Genovese, Partner, Arthur Young & Co., Boston. Their opinions were communicated privately.

gains from tax savings). However, these factors tend to vary significantly by industry, and hence the figures in Table 19 suggest that these were not important determinants of the choice to use FIFO. The use of subsamples to check for stability of coefficient estimates is a useful method for examining sample selection bias. The uniformity of results across five different samples suggests that sample selection bias may not be a serious problem.[55]

In sum, tests involving different specifications and subsamples confirm a secular rise in OB/FGI, in accordance with our predictions that there has been a shift from building to stock to building to order. In a previous section of this thesis growth in intraindustry trade (IIT) was used as an indicator of industries in which flexible production may be increasingly prevalent. A distribution of industries ranked on the basis of growth in IIT was found to be very highly correlated with the distribution generated on the basis of the magnitude of shift in the skill composition of production employment. A similar industry analysis was conducted using the Compustat data. The results, discussed below, are mixed.

Table 21 shows regression results for durables and non-durables industries from the total sample (column 1 of Table 20) and the FIFO only, no changers sample (column 6 of Table 20). While the estimates vary

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[55]More careful explicit treatment of the sample selection problem (e.g. "Heck-it") in this case would be exceedingly involved, since firms often change methods more than once. Each period's choice could then have to be modelled conditionally on previous choices. The results suggest that further work along these lines would not be fruitful.

little between the total and FIFO samples, there is a striking difference between the durables and non-durables industries. The estimated coefficient on the time trend for non-durables is much larger and more precisely estimated than for durables. Indeed, the point estimate for non-durables implies a four percent annual increase in OB/FGI. The other estimated coefficients in the non-durables samples are also more precisely estimated than in the durables samples, but the signs on the interest rate and inflation terms remain counterintuitive.

The final row in the top panel of Table 21 shows that durables industries have, on average, much higher OB/FGI ratios. The regression results indicate that this gap is narrowing over the sample. However, this does not bode well for matching industries with the results from the skill composition data, since the latter was dominated by upskilling in durables industries (with some exceptions). The lower panel of Table 21 lists those industries which had significant positive coefficients on the time trend in each case. Leather is a small and idiosyncratic case in the Compustat data (1.5% of the sample), but otherwise the remaining three industries appear, too, in the other column (there are no paper firms in the FIFO sample). Petroleum remains an outlier, while in the case of machinery there was a positive but insignificant estimated time trend in the FIFO data. Interestingly, the estimated time trend for electrical machinery is negative but insignificant, which is consistent with the lack of a shift to skilled workers. Thus, there is some uniformity in the top portion of both rankings.

However, when the entire list of industries is ranked on the basis of the estimated magnitude of the time trend coefficient in the OB/FGI regressions, and the ranking is compared to that from the CPS skill composition data, the Spearmen rank correlation coefficient is nearly zero. Thus while the industries at the top of both lists are very similar, these two models do not generate closely correlated rankings for the remainder of the distributions. This is due in part to the idiosyncrasies of the leather and petroleum industries. Their exclusion from the lists improves the rank correlation coefficient, but does not make it significant. The fact that Compustat includes only large public firms, while the CPS data came from workers in firms of all sizes, and differences in the time periods in the two samples (1970-87 vs. 1973-85) respectively), may also generate some of the discrepancies. The differences between the behavior of the non-durables and durables industries in the two models are also clearly important.

This section set out to show that the new theoretical models of Milgrom and Roberts (1988a,b) were very close to the case study evidence and to the model pursued in this thesis. The central testable implication of these models was shown to be consistent with the analysis of the previous sections. In fact, the test for a relative shift to production to order rules out several of the competing hypotheses raised in the context of the upskilling results. Empirical work was then presented which showed that, despite formidable accounting problems, there is clear evidence of an increase in OB/FGI. A comparison of the industries identified as moving most toward flexible production using this model and the skill composition model yielded mixed results; conformity at the top of the distribution, but little correspondence thereafter. Nonetheless, the results from this section provide supportive evidence that the changes in the skill composition of production employment documented above were generated by changes in the organization of production.

C. Alternative Explanations for the Shift to Skilled Workers

We have already demonstrated that simple labor supply changes cannot explain the skill composition data. Perhaps the most obvious demand story is that the demand for more skilled workers has risen steadily over a long period of time. Table 2, however, shows that there is no evidence in employment share data for a secular rise in skill demands. Instead, the data suggest that structural change -- in particular, the growth of mass production -- increased greatly the share of semi-skilled operatives who manned the mass production machinery.

The lack of an increase in the craft share of manufacturing employment is not surprising if viewed in the context of the ongoing debate over automation and deskilling. Braverman (1974) argues that automation moved many workers from the laborer occupations to the operative occupations simply by bringing them into contact with mass production machinery, without raising skill requirements at all.

Meanwhile, automation and its increased division of labor tends to reduce the need for craft, or more general, skills. There is, therefore, nothing in his analysis to support the prediction of a secular rise in the demand for skilled production labor. Furthermore, a well-known study by Bright (1958) reported on detailed analyses of thirteen of the most advanced production systems in operation in the mid-1950s. On the basis of this research, Bright concludes that there was a **negative** relationship between skill requirements and mass production automation.

A recent study provides an extensive review of research on the relationship between technological change and the skill composition of employment. Spenner's (1988) review of the literature for the National Academy of Science includes research whose sample periods range from the late 19th century to the 1980s. He concludes that, despite extensive research:

> The major positions in the debate - the upgrading, downgrading, and mixed-change or conditional arguments - have failed to receive a clear verdict from the collective body of evidence... Compositional shifts appear to account for relatively more of the upgrading; <u>content shifts appear to account for more of the downgrading</u>. (pp. 174-75, emphasis added)

Thus there is no obvious presumption that technological change, alone, leads to the upgrading in skill requirements identified in this thesis. In fact, Spenner agrees that non-technological factors are critical for skill requirements:

> Most important, the effects of technological change on the skill requirements of work are set in a larger context of market forces, managerial prerogatives, and organizational cultures, all of which condition the effects of technological change. The force of

> managers, markets, and organizational cultures are sufficient to reverse the effects of a technology on skill upgrading or downgrading. (p. 132)

In its study of the skill consequences of information technologies, the OECD (1988), too, argues that while information technologies have the potential to raise skill requirements, the outcome hinges on work organization and managerial behavior.

A second alternative explanation is that only recent technological change in capital requires more highly skilled workers. The argument is that while technological change per se may not raise the skill requirements of production workers, recent technological change has been concentrated in the application of information technologies which do tend to raise skill requirements. There are two variants on this position. In the first, upskilling takes place within the confines of mass production. Alternatively, technological change itself lowers the cost of flexible production and induces the shift from mass to flexible production; there need be no stimulus from product markets. In the Milgrom and Roberts model, such a shift is triggered by reductions in new product set-up costs and the costs of surveying potential customers. More generally, reductions in unit costs for small batches and lower retooling costs are cited as motivations for flexible production.[56]

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[56]Milgrom and Roberts (1988b) cite several examples:

- a recent survey of aerospace and other high precision industries indicates that 8.2 percent of all batches were of size one and 38 percent were sixteen or less;
- Allen-Bradley Co., a maker of electric controls, is reported to produce 725 products and variations with a minimum batch size of one and an average changeover time for resetting equipment of six seconds;

It is possible to distinguish conceptually between a shift to flexible production as a result of technological change and a shift due primarily to changes in product markets. In practice, these two forces may be connected, and data do not exist for the key characteristics of either. Consequently, it is very hard to prove attribution to one or the other in a large sample. For many purposes such attribution is unnecessary, since the resulting relative shifts in the demand for workers by skill group obtain in either case. However, it is important to understand the separate roles played by product market conditions and technology in order to anticipate the effects of changes in one or the other (e.g. changes in product market competition resulting from rising wages abroad). In what follows, evidence is presented which supports product market conditions as the stimulus to flexible production.

The timing of changes in production regime provide critical evidence in this regard. Milgrom and Roberts (1988b) correctly point out that, "Moves towards 'the factory of the future' have involved discrete, discontinuous and substantial changes in a whole range of the firm's activities." (p. 3) In their model this is the result of exogenous input price changes triggering action which, due to complementarities among the components of flexible manufacturing, lead to large discontinuous changes.

- Benetton, an Italian apparel manufacturer, maintains inventories of undyed clothing and uses nightly sales data - telecommunicated from each store - to determine what colors to make and where to ship the output.

Specifically, reductions in the costs of product design and the costs of flexible manufacturing equipment stimulate the shift. Once the investment in flexible equipment has been made, there is an incentive for frequent product changes. This leads to the purchase of computer-aided design (CAD) technologies, which lower the cost of changing the product, and so on. While the model is static, the implicit dynamics envision technological progress simply arriving at a point where the costs are low enough to trigger the change.

One simple way to test for the role of technology in generating the shift to skilled production workers is to recognize that when the change in production regime takes place in the Milgrom and Roberts model, firms must invest in new capital equipment. Hence there should be a contemporaneous relationship between investment and changes in the skill mix. This hypothesis was tested by adding investment in nonresidential equipment to equation (5). The results were no change in the level or significance of the time trend and an insignificant coefficient on the investment variable. One year lags yielded similar results. Better measures of technological change would be preferable, but if technology is the driving force its effect should be evident using the investment data.

The case study evidence cited above and interview evidence from the Piore (1987) project suggest that product market conditions are the critical factor. Improvements in flexible manufacturing technology have been ongoing for many years. The decision to reorganize production at the firm level was always driven by important changes in the product market, typically involving the onset of lower cost/higher quality competition. In many cases the changes in product markets were sufficient to jeopardize the existence of the company. Managers then searched for answers in the form of new business strategies. New technologies were certainly put to use in support of these strategies, and in some cases the technologies influenced the formulation of the strategy itself. But, it was not the case that firms facing tranquil product markets suddenly observed a recent technological change and transformed their organization and business strategies to capitalize on it.

The experience of Xerox Corporation is a useful illustration. Xerox had been a highly profitable producer of photocopying equipment and up until the late 1970s had a very large market share. In the mid to late 1970s many firms - Kodak and several Japanese firms - developed the knowledge necessary to introduce copiers that were cheaper, higher quality and easier to service that Xerox's product line. Furthermore, these firms were able to introduce new products faster than Xerox, which made it very difficult for Xerox to catch-up. Xerox managers discovered that a large part of their deficiency lay in the fact that they designed and built copiers with many more parts and much more complicated designs than did their competitors. The results were higher parts costs, much longer design lead-times, lengthy assembly processes, frequent malfunction and difficult repair procedures. Among the reforms initiated in response to the crisis was a unification of the formerly sequential engineering process. Rather than having design engineers, working in isolation, "hand-off" completed plans to manufacturing engineers who then had to figure out how to build the product, teams were formed that included designers, manufacturing engineers, marketing and service staff. The teams were given extensive computer-aided design/computer-aided manufacturing (CAD/CAM) resources, but not because the technology got cheaper: CAD/CAM capabilities were better exploited by the teams. CAD/CAM keeps the design fluid, as designs need not be committed to paper and prototypes need not be built. This facilitates the team approach by allowing frequent design modification by all parties without forcing the engineers to start over each time.

Examples of this sort are plentiful, and the central point is clear: technology is an important enabling factor, but it is rarely the cause of substantive reorganizations from mass to flexible production.[57] Zuboff (1988) focuses on the organizational consequences of the spread of information technologies (IT), and shows that the implications for job content are by no means clear. She distinguishes between two capacities of information technologies: automating and informating. The former refers to automating operations "according to a logic that hardly differs from that of the nineteenth-century machine system." The latter refers to the "simultaneous generation of information about the underlying productive and administrative processes through which an organization accomplishes its work. It provides a deeper level of transparency to activities that had been either partially or completely opaque." (p. 9) Zuboff's evidence shows that the automate or informate decision is not technologically determined, but rather is idiosyncratic to the

[57]See Piore (1987) for a few more examples.

circumstances of the firm. The choice, however, has profound implications for job content. Automation often involves deskilling, while informating gives workers more information and increases their responsibility for inspection (quality), repair, coordination, decision-making, and planning.

These changes are fundamentally a response to firms' decisions to compete on the basis of customized, high quality goods rather than on the basis of cost for commodities produced with an extensive division of labor. Hirschhorn (1984), for example, argues that preparation and learning are becoming the core elements of production work because mechanical (or process) failure is an increasing function of quality standards and product variety. When General Electric reorganized one of its electrical distribution equipment plants in an effort to increase product variety and reduce delivery time, the tasks performed by production workers changed dramatically. The New York Times (10/17/88) reports that a production worker's job changed from machine set-up man to a collection of tasks including resolution of machine malfunctions, planning and ordering parts for future machine maintenance, and membership on a committee that interviews job applicants.

In sum, it is difficult to attribute responsibility for the shift to flexible production to product market factors or pure technological factors. The case study evidence, however, suggests that product market considerations were primary and technology was enabling. Furthermore, what data are available do not support the claim that technological change was the crucial factor.

Finally, outsourcing of the lowest skilled components of production to other countries is a possible, although not very likely, explanation for the rising share of skilled production workers. The premise is that mass production processes can be cleanly divided such that the low skill end can be exported. While exporting production generally is feasible, the justification for exporting the low end is less clear. For example, subcontracting of component production may be undertaken outside the U.S., but the remaining domestic assembly process will involve largely low skill assembly jobs. In this common example, the effect of outsourcing would be to lower the share of skilled production workers (note: it may raise the share of skilled workers overall, including white collar workers). Hence it is not easy to simply export the low skilled production jobs only. Moreover, fixed proportions technologies imply that some skilled workers are needed to set-up the machines, make the tools and dies, etc. In addition, outsourcing is a technique for arbitraging labor cost differences. It is not obvious, however, that the savings are greater for low skill production work than for high skill production work.

Furthermore, in the interviews associated with Piore (1987) we were told repeatedly that outsourcing production abroad had been a problem because production was taking place too far away from design and engineering: it was too difficult to change the components in response to the demands of new products of better quality. Indeed, many firms were consciously bringing production of components back as close as possible to their main production and engineering facilities as a part of their overall reorganization for more flexible production. Consequently, while outsourcing is not observable in our data and hence cannot be ruled out formally, it does not seem likely to be a big part of the reason for the observed shift to skilled production workers.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

A. Recapitulation

This thesis began with a reference to the decline in U.S. industrial competitiveness, and to a diagnosis that places much of the blame on inadequate organizational structures and poorly trained workers. The central hypothesis of this thesis has been that a fundamental change in the organization of American manufacturing from mass to flexible production can be tested for by examining changes in the composition of production employment by skill group. In other words, there is indeed a critical connection between changes in the organization of production and the training, or learning, required of workers. The relationship between the skill requirements of workers and a shift from mass to flexible production was illustrated with case studies from firms that have reorganized for flexible production. The critical element in these case studies was the change in the nature of work performed by production workers, and changes in the relationships between workers. Rather than performing a very limited number of repetitive tasks in isolation from other parts of the production process, as was the case in mass production, workers involved in flexible production perform a broad and varying range of tasks and often work in teams with both other production workers and white collar workers. This very different type of work requires chronic learning, and requires workers to have a conceptual understanding of the overall production process. Consequently, firms that use flexible production will shift their hiring towards groups for whom learning, or training, is least costly. It is worth emphasizing that persistent change in products and job tasks is critical to this argument. If firms simply shift from mass producing one product to mass producing another, perhaps more sophisticated product, it behooves them to again use a highly specialized division of labor and cheaper unskilled workers. It is only when frequent learning is required that firms will seek workers whose higher wages are justified by lower training costs.

A simple model was presented to formalize these ideas. Firms were modelled as employing two types of workers, skilled and unskilled, and these workers required training to produce each new product. It was shown that as the length of product life-cycles declines, relative employment shifts toward the group whose training costs are lowest, unless relative wages adjust sufficiently to offset the difference in training costs. Model simulations of reductions in product life-cycles were presented which showed that, for plausible parameter values, downward movement in the relative wages of the unskilled were not likely to be sufficient to offset the training cost advantage of skilled workers. Hence, the model predicts that reductions in product life-cycles induce a shift in the composition of production employment favoring skilled at the expense of unskilled production workers. In other words, a testable implication of a shift to flexible production is a shift in relative labor demand toward skilled workers. The model also yields labor demand functions to test for changes in relative demand.

Chapter II presented substantial empirical evidence to show that labor demand has indeed shifted in favor of skilled production workers. Detailed occupational data from the Occupational Employment Statistics showed a significant increase in the share of skilled workers in the total production employment of the four largest durables manufacturing industries. Relative wage data were presented which showed, if anything, a mild increase in the relative wages of skilled workers. These two facts together are evidence of a shift in relative labor demand. However, more rigorous testing for shifts in labor demand was conducted using the May Current Population Survey. Data on the wages, occupation and industries of employment of individuals were used to construct a panel data set in which each observation is an occupation by industry by year cell. The panel covers two occupational groups, skilled production workers and an aggregate of semi and unskilled production workers, and twenty two-digit industries annually from 1973 to 1985. Since product life-cycle data are not available, a simple time trend was used as a proxy. The results from instrumental variables estimation of the labor demand equations is a significant shift, both economically and statistically, toward skilled workers. This change in the relative demand for labor is an important finding irrespective of its cause. When combined with the long run shift from production to white collar employment, the results indicate a severe decline in the employment prospects of unskilled workers.

These findings are consistent with recent research showing a large decline in the relative wages and employment of less educated workers.

Indeed, the current state of research on changes in the relative wage structure finds a large, unexplained within-industry decline in the relative wages of the less educated. This thesis provides a promising explanation for the currently unexplained within-industry shifts in labor demand generating the changes in relative wages. However, this thesis focuses on manufacturing production workers while the relative wage structure research includes all workers. An attempt to generalize the findings of this thesis awaits further work.

Chapter III employs international comparative methodology to test the hypothesis of a change in the organization of production. If the factors stimulating change in the U.S. are present elsewhere, the shift should also be occurring elsewhere. Variance in institutional structures and history should generate testable predictions about cross-country differences in the timing and magnitude of the changes in the organization of production. Perhaps most importantly, the international comparisons hold constant variables such as technology, and thereby permit more powerful tests of the central hypothesis of this thesis. In particular, Chapter I suggests the critical role played by the supply of skilled workers in influencing the choice of production method. Germany and the U.K. provide a stark contrast in vocational training systems that should, if the model is correct, be reflected in differences in the organization of production. It was shown that the German dual vocational training system provides a large supply of certified craftsmen whose training is very well suited to flexible production. Essentially the contrary is true in the U.K. Furthermore, rigid craft job demarcations in the U.K.

severely inhibit changes in the task structure. The testable implications are, then, that Germany should have used flexible production more pervasively even years ago, as reflected in higher employment shares for skilled workers; both countries should have experienced a shift to skilled workers in recent years; and, the shift should have come earlier in Germany.

Employment composition data from Germany and the U.K. were presented which confirm the predictions. Germany has a very large share of skilled production employment, compared both to the U.S. and U.K., and the share rose significantly from the early 1970s to the early 1980s. The U.K., on the other hand, has a much smaller share of skilled workers, and the share rose significantly only in the 1980s. A case study from the British auto industry shows in detail the significant changes experienced by British industry around 1980. Finally, a case study is presented which shows how the machine tool industry was for decades organized around flexible production in Germany while being based on mass production in the U.S., and discusses why the German industry responded so much better to the crisis that hit the industry worldwide in the 1980s.

Chapter IV further attempts to identify the cause of the changes in relative labor demand by articulating testable implications of flexible production that are based on non-labor data and, hence, are less subject to alternative explanations. First, a case is made for intraindustry trade as a proxy for the product differentiation strategies associated with flexible production. If this case is valid, the index of intraindustry trade should have risen in those industries where there was a shift from mass to flexible production. Intraindustry trade is calculated for each of the two-digit SIC manufacturing industries from 1958 to 1984. Changes between the periods 1958-73 and 1974-84 are calculated for each industry and a ranking is made on the basis of the change. This ranking is found to be significantly positively correlated with a ranking made on the basis of the shift to skilled production workers. The results suggest that, to the extent that increases in intraindustry trade are a proxy for reductions in product life-cycles, reductions in product life-cycles are an important cause of the shift to skilled workers.

Second, current theoretical work by Milgrom and Roberts (1988a,b) is used to generate a testable implication of the shift from mass to flexible production that is based on the choice between building to order or building to stock. In short, when firms are mass producing a single product, inventories are an effective means for responding to uncertain demand for that product. When, on the other hand, product differentiation strategies lead firms to produce a wide and varying mix of products, inventories are very costly as many products must be held and consumers' specialized demands may not be met by inventoried goods. Consequently, production to order may be preferable. The simple testable implication is, therefore, that if firms are moving from mass to flexible production, the ratio of order backlogs to finished goods inventories should increase.

Compustat data on publicly traded companies from 1970 to 1985 are used to test for an increase in this ratio over time, controlling for variables known to influence inventory behavior (e.g. the interest rate). The analysis is complicated by changes in accounting methods for inventory valuation, but the use of many sub-samples yields a robust result that the ratio of order backlogs to finished goods inventories has indeed risen. Efforts to rank industries on this basis and compare the ranking to that based on the labor data provided mixed results: considerable uniformity at the top of the ranking, but little correlation elsewhere. Thus the results support the hypothesis of a shift to flexible production overall, but the industry level behavior cannot be linked clearly with changes in the skill composition.

Third and finally, Chapter IV considers alternative explanations for the observed shift to skilled production workers. It bears repeating that the focus on production workers excludes traditional technological change stories based on white collar for blue collar, or capital for blue collar substitution. In fact, time series data from 1900 forward were presented to show that the shift to skilled production workers is not the continuation of a long-standing trend caused by, say, secular technological change. A review of the literature on technological change and job content was presented which shows that there is no clear relationship between technological change and increases in skill requirements of production workers. Quite the contrary, important studies of automation in mass production found reductions in skill requirements. Outsourcing of low skilled jobs abroad is also considered, and found to be an unlikely explanation.

The alternative that is most likely to be an important factor in the change in relative labor demand is that recent technological change, rather than product market conditions, led firms to shift to flexible production. While the qualitative evidence on the technology and job content is mixed, it is certainly possible that information technologies have raised the skill requirements of workers by increasing their information processing and decision-making responsibilities. Inclusion of investment variables in the labor demand equation as a proxy for technological change yields insignificant coefficient estimates and does not alter the magnitude or precision of the time trend coefficient. But more importantly, extensive case study evidence of firms moving to flexible production suggests that the stimulus came from heightened competition in product markets, and technology was an enabling factor. If technology were primary, the organizational changes should have been coincident with technological changes. In fact, the organizational changes were coincident with changes in product markets, such as the loss of market share to international competitors.

In sum, the empirical evidence supports the hypothesis that a shift in the organization of production from mass to flexible production has taken place in the U.S. from the mid 1970s to the mid 1980s. This shift has been manifested by an increase in the relative demand for skilled workers, resulting in a deterioration in the employment prospects of the unskilled. International comparisons involving Germany and the U.K. show that the changes in the organization of production found in the U.S. are also at work in other western industrialized countries, but the nature and extent of the shift vary in predictable ways as a function of historical and institutional circumstances.

B. Methodological Issues

The methodology pursued in this thesis is atypical, but so too is the nature of the problems under consideration. Changes in the organization of production are systemic, involving a wide range of variables that define and influence an organizational structure. Many of the important variables, such as product life-cycles, are difficult to define tightly and even more difficult to measure. Others may be subjected to influences in addition to those generated by the change in production methods; e.g., the composition of employment in a particular industry may be affected by technological or trade-induced changes idiosyncratic to that industry.

The most common response to these difficult methodological problems has been to use case studies, which control for most of the problems by severely limiting the sample. The results, of course, are equally limited. This thesis attempts to move research on changes in the organization of production more into the mainstream of modern economics by, first, introducing a simple formal model, and, then, testing hypotheses on large sample data using econometric methods. The results do not demonstrate the verisimilitude of one hypothesis to the exclusion of all others. Rather, the collection of results makes a strong case for a shift from mass to flexible production, and shows that there has, in any case, been a shift in relative labor demand favoring more highly skilled production workers in the U.S., Germany and the U.K. If these problems are actually important, less than conclusive evidence may have to suffice until new data collection and research mature sufficiently to provide more precise evidence. There is, however, a clear tradeoff: efforts to narrow the research to yield more convincing results threaten to undermine the intrinsically systemic nature of the issues.

C. Policy Recommendations

If flexible production is preferable to mass production in the current economic environment, its emergence and institutionalization should be a beneficial phenomenon. Policy concerns arise, then, from two sources: remedying any adverse effects suffered by particular groups in the adjustment process; and, fostering institutions that both facilitate the adjustment and maximize the long-term effectiveness of flexible production in the U.S. With respect to the former, this thesis has shown that the employment prospects in manufacturing for unskilled production workers have clearly deteriorated. More generally, the U.S. relative wage structure research has shown that less educated workers have suffered large relative wage and employment losses overall (i.e. over all sectors of the economy). Indeed, since unskilled manufacturing production jobs offer wages far in excess of unskilled service jobs, the loss of the unskilled manufacturing jobs is a severe blow even if other employment is available. Blackburn, Bloom and Freeman (1989) show that this sort of sectoral recomposition of employment accounts for a significant portion of the relative wage losses suffered by less educated workers.

In addition to wage losses, the change in relative labor demand may also have significant unemployment consequences.[58] Workers often experience unemployment spells even if they subsequently are successful in finding work elsewhere. Less fortunate workers may either exit the labor force, or wind-up in long-term unemployment. The large wage gap for unskilled workers between manufacturing and other sectors may induce workers to wait in unemployment in the hope of finding reemployment in manufacturing. Katz's (1986) work, for example, shows workers' willingness to wait extensively for recall to jobs in durables manufacturing. In the U.S. vigorous overall employment growth mitigates the transitional unemployment problem, but in most western European countries slow overall employment growth aggravates the difficulties faced by the unskilled in finding alternative employment.

Since the transition that is generating the shift in labor demand

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[58]In Germany, Kern and Schumann (1988) argue, on the basis of extensive case study research that:

> A particular group is precluded from joining the workforce because its members do not hae the qualifications prerequisite for employment in a modern plant. These persons are burdened with the risk of becoming unemployed and must fear long-term unemployment sooner or later. (p. 23)

is desirable, policies should not be put in place that retard adjustment. The pure efficiency grounds for policies to assist workers experiencing unemployment or wage losses are, therefore, ambiguous, because it is possible that these costs may expedite adjustment. It may be, however, that policies aimed at facilitating workers' movement from manufacturing to other sectors may enhance efficiency by reducing transitional unemployment.[59] Specifically, policies aimed at increasing the mobility of unskilled workers, providing training to unskilled workers, and, at the local level, regional development policies designed to foster job growth in proximity to where job losses are taking place, are the most promising candidates. Sweden's labor market program is a useful model. It spans all of these dimensions, and its interventions are designed to quickly reallocate labor away from declining industries and occupations and toward expanding ones.[60]

Policy has a much less clear role in addressing directly relative wage losses. A more attractive alternative is to encourage the training necessary for unskilled workers to acquire more highly skilled jobs. This may be accomplished via subsidies to employers who provide training, publicly provided training, or subsidies to individuals who undertake private training (e.g., vocational/technical schooling).

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[59]Research (Jackman and Layard (1988) and Blanchard and Summers (1986)) has shown significant duration dependence in unemployment, which suggests that in order to be most effective, these policies must embrace workers quickly after they are disemployed.

[60]See Standing (1988) and Bjorkland (1986) for descriptions of Sweden's system.

Reform to training institutions is a vital, perhaps the vital, institutional change needed to support the long-term health of flexible production in the U.S. Piore and Sabel (1984) discuss the broad scheme of institutional reform required to support flexible specialization. The remainder of this section is limited to a brief discussion of vocational training, since the provision of skills has occupied a central role in this thesis.[61]

Vocational training in the U.S. is, in a word, diverse. Unlike the German system, vocational training takes place in many places and in many forms. An apprenticeship system exists which is accredited by the federal government, but it provides only a small portion of the skilled workforce. While the apprenticeships define the crafts themselves, many workers enter the crafts by obtaining "equivalent" qualifications from alternative sources. Employers are also large providers of training which is itself quite diverse, ranging from formal classroom instruction to informal on-the-job training. Employers in many cases cooperate with local technical or vocational schools in the provision of particular curricula, or employers simply hire the graduates of such schools and supplement their training with firm-specific skills.

Maurice et. al. (1986) argue that education, business organization and industrial relations are all inextricably connected in any nation's institutional structure, and this is certainly true in the U.S. The

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[61]For a more complete discussion of the training implications of a shift to flexible production, see Loveman, Piore and Sengenberger (1988).

essentially chaotic U.S. training system reflects the largely unstructured nature of American labor markets and the diverse nature of industrial relations (e.g. craft versus industrial unions, and low union density generally). It is also the product of the lack of compulsory training past the minimum school withdrawal age of sixteen. In this context, the imposition of a much more highly structured system, such as the German system, is simply not feasible, despite its many virtues.

Rather, the needs of flexible production for skilled workers must be met through adaptation of the existing structure. There are obviously large private incentives for firms and workers to establish effective training systems, but coordination and accreditation remain problematic. One of the great advantages of the German system is formal and rigorous accredation which makes skills portable across firms. Employer-provided, or otherwise idiosyncratic training such as that most often found in the U.S. is much less portable. Employers may wish to establish skill recognition agreements with suppliers or through trade associations to facilitate workforce adjustments in response to demand shocks. Portability -- greater general training -- may reduce firms' willingness to pay for training, hence increasing the need for better institutional arrangements to promote training. The shrinking presence of unions is a drawback in this regard, since unions could act as the source for skill accreditation.

In addition to private incentives, government policy could be effective in expanding the scope of the existing apprenticeship system, improving its quality, and better coordinating its content with employers and unions. Financial aid to workers pursuing apprenticeship or equivalent training is also desirable to more rapidly increase the supply of skilled workers. Finally, America's success in generating a satisfactory vocational training system is clearly predicated on the need for pervasive high quality elementary and secondary education.

CHART 1

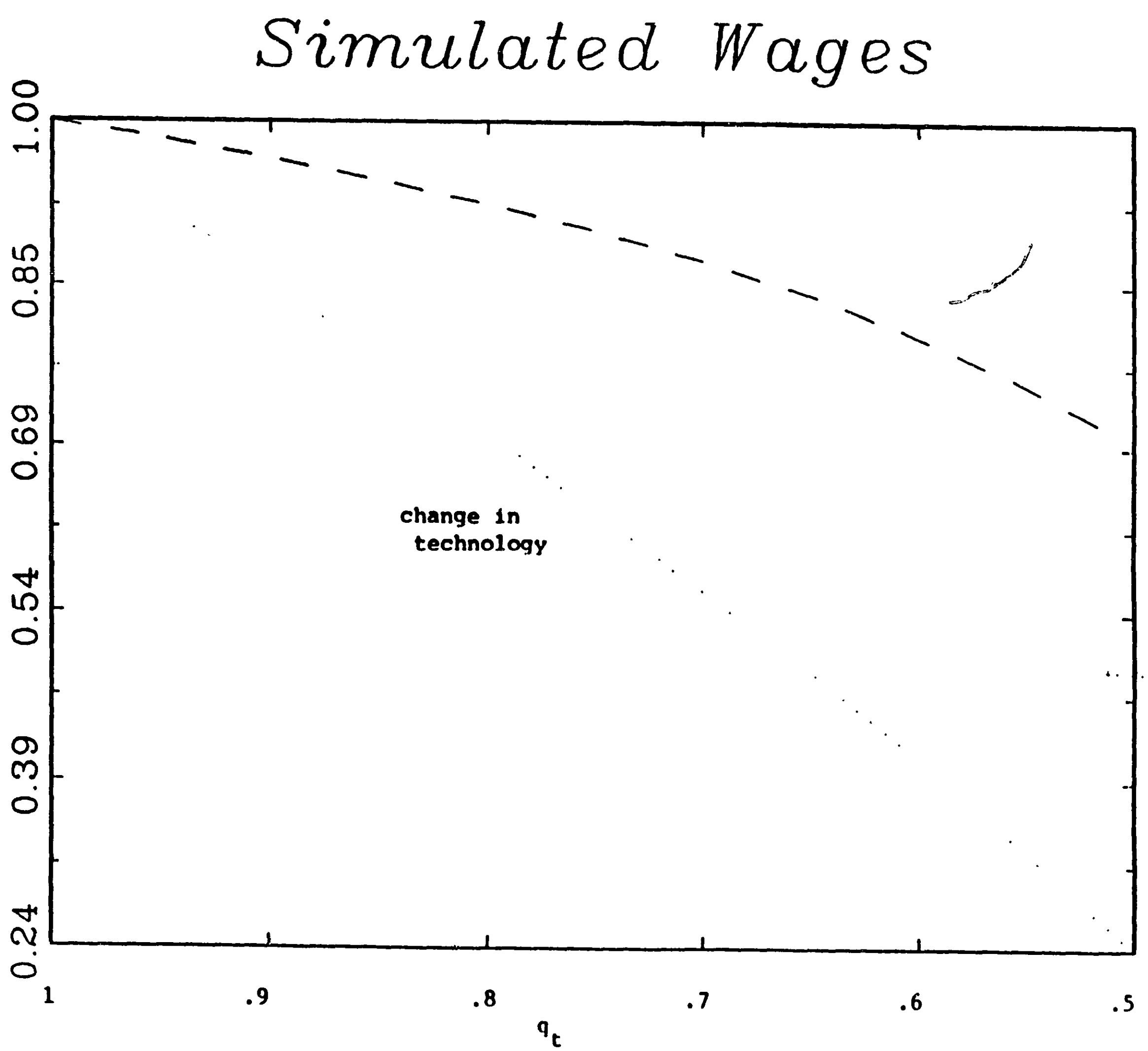
Simulated Wages
1.00
0.85
0.69
0.54
0.39
0.24
1
.9
.8
.7
.6
.5
q_t
change in
technology

CHART 2

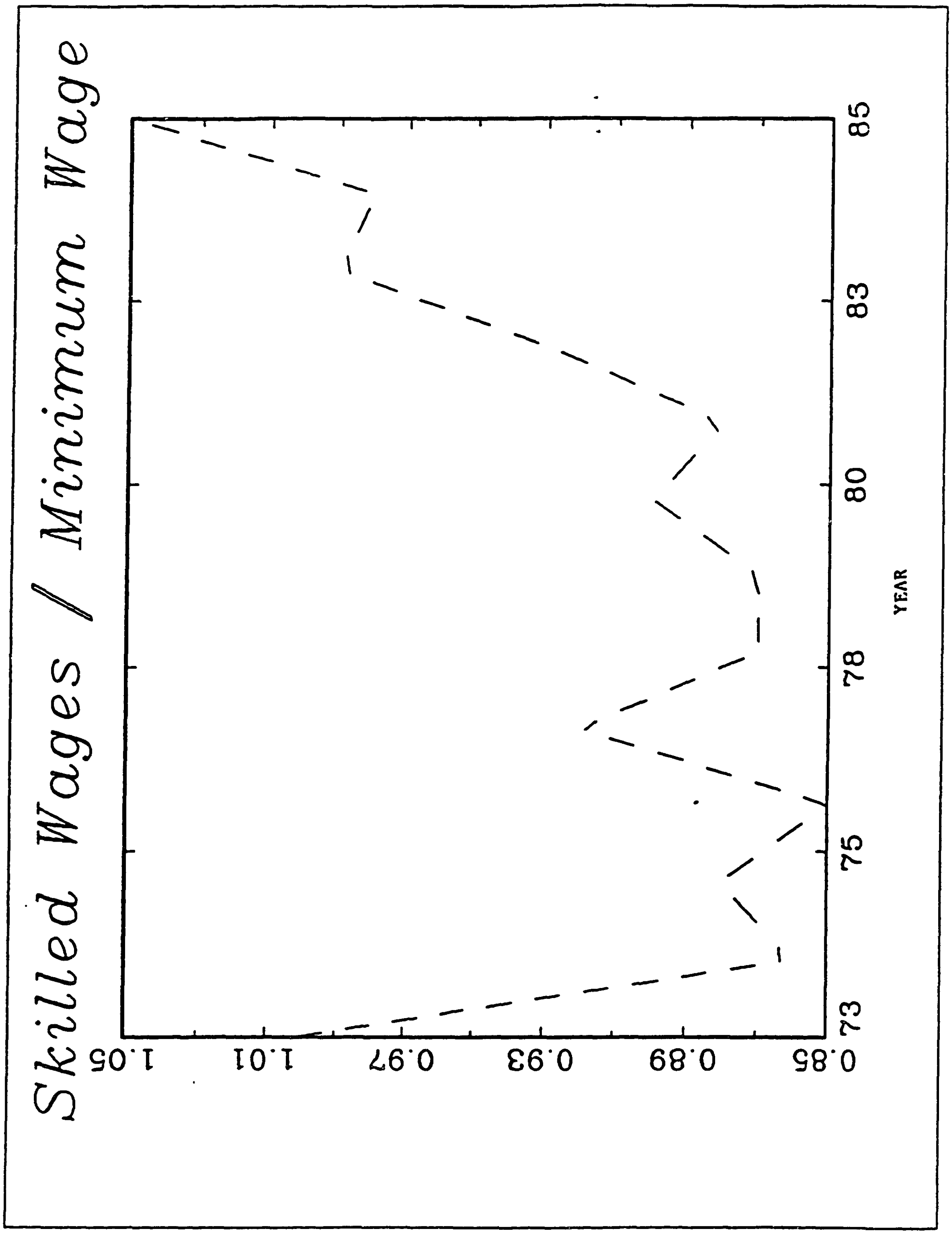
Skilled Wages / Minimum Wage
1.05
1.01
0.97
0.93
0.89
0.85
73
75
78
80
83
85
YEAR

CHART 3A

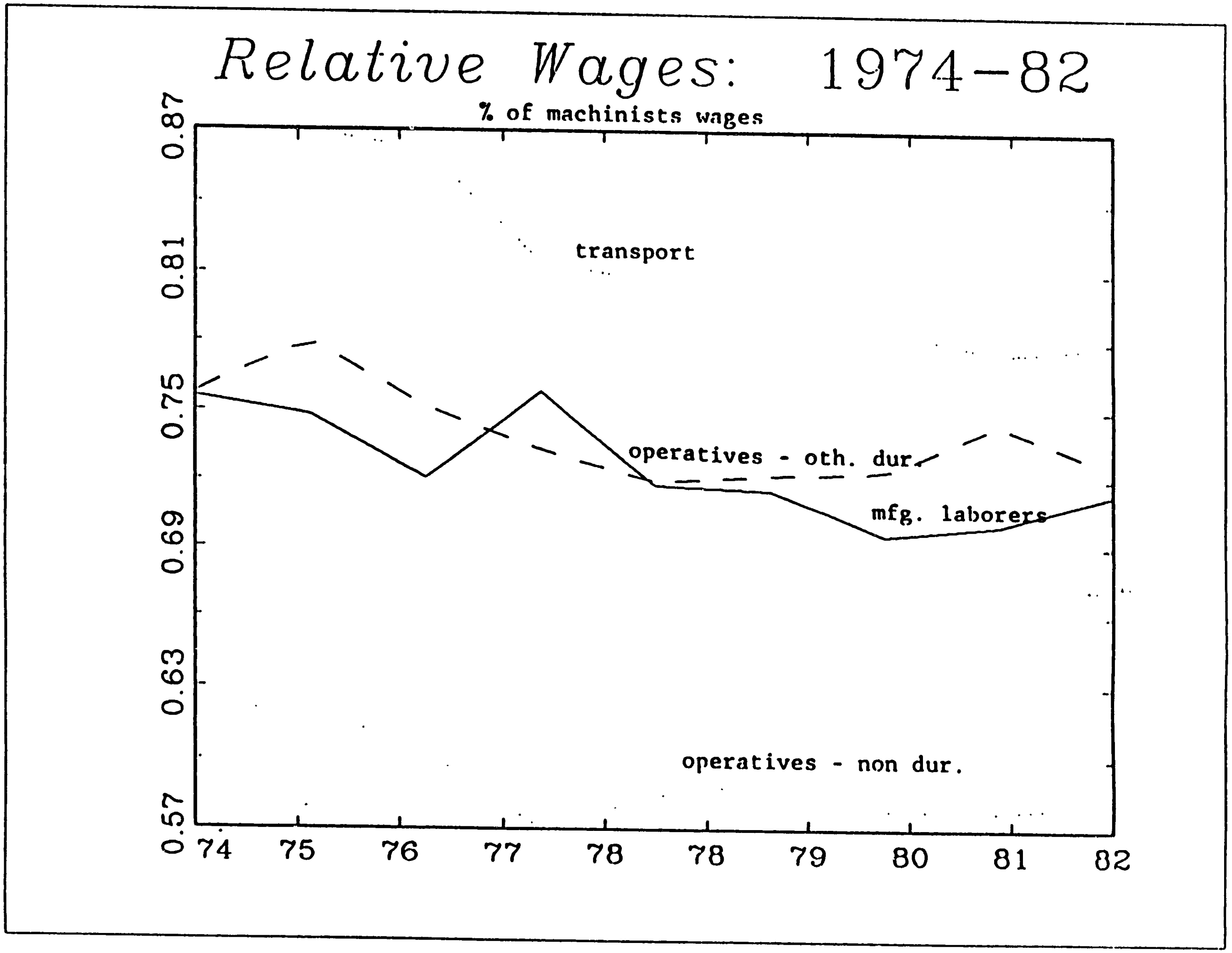
Relative Wages: 1974-82
% of machinists wages
0.87
0.81
0.75
0.69
0.63
0.57
74
75
76
77
78
78
79
80
81
82
transport
operatives - oth. dur.
mfg. laborers
operatives - non dur.

CHART 3B

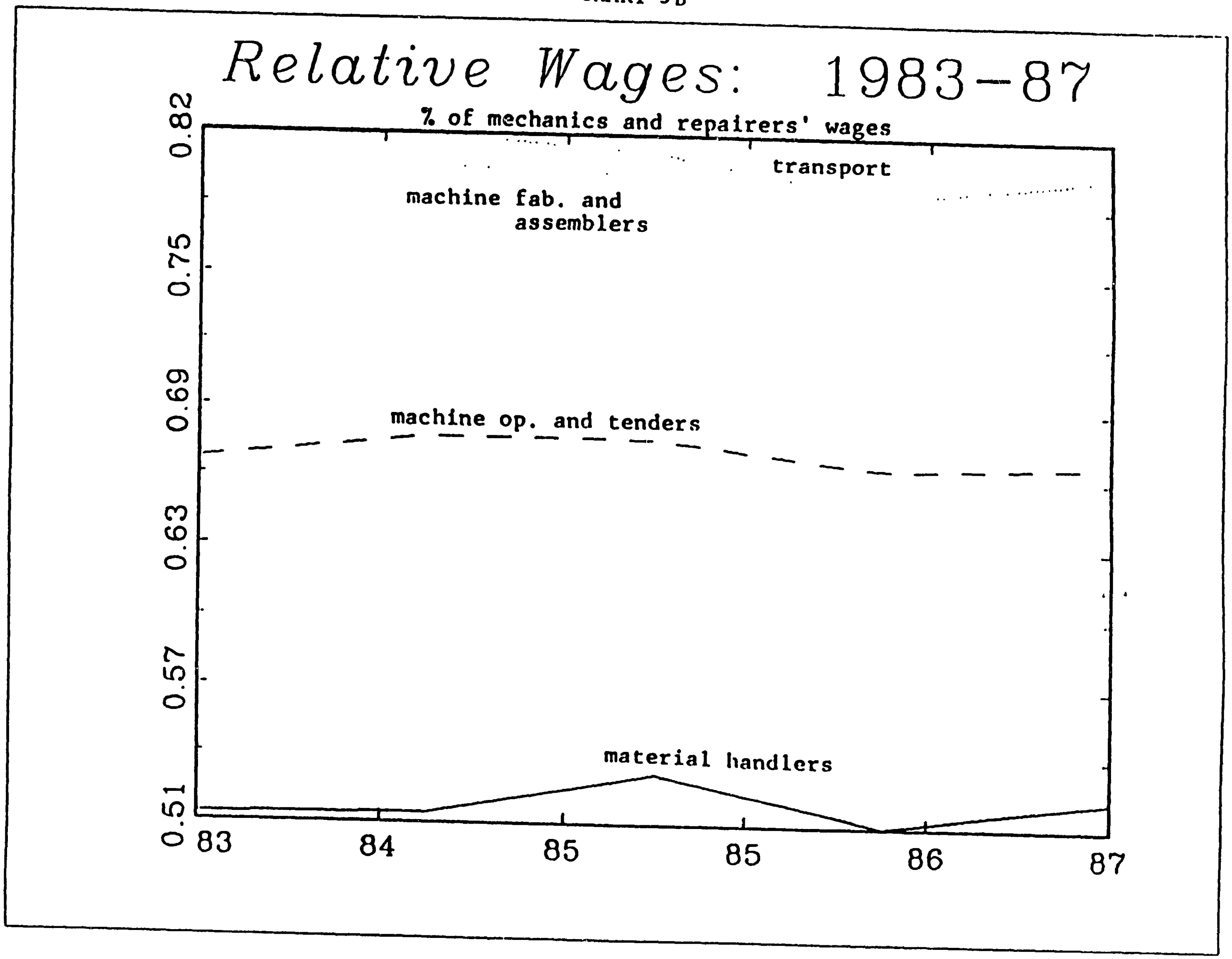
Relative Wages: 1983-87
% of mechanics and repairers' wages
transport
machine fab. and assemblers
machine op. and tenders
material handlers
0.82
0.75
0.69
0.63
0.57
0.51
83
84
85
85
86
87

Chart 4

Trends in Wage Differentials, 1963-1986

Ratios of Average Weekly Wages

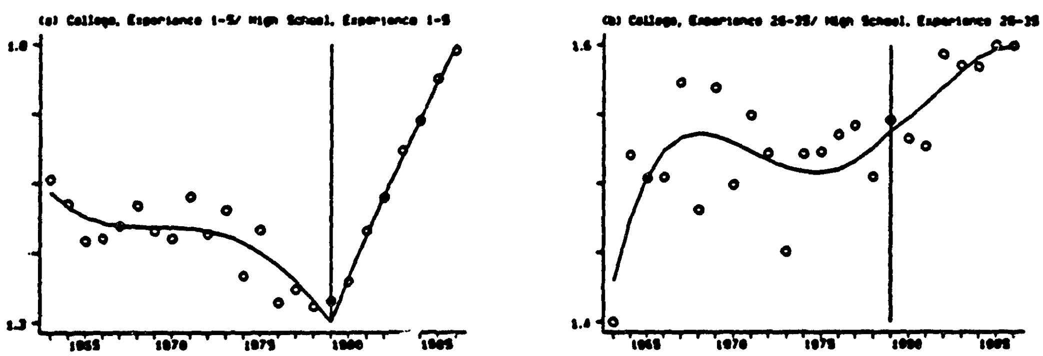

Chart 5

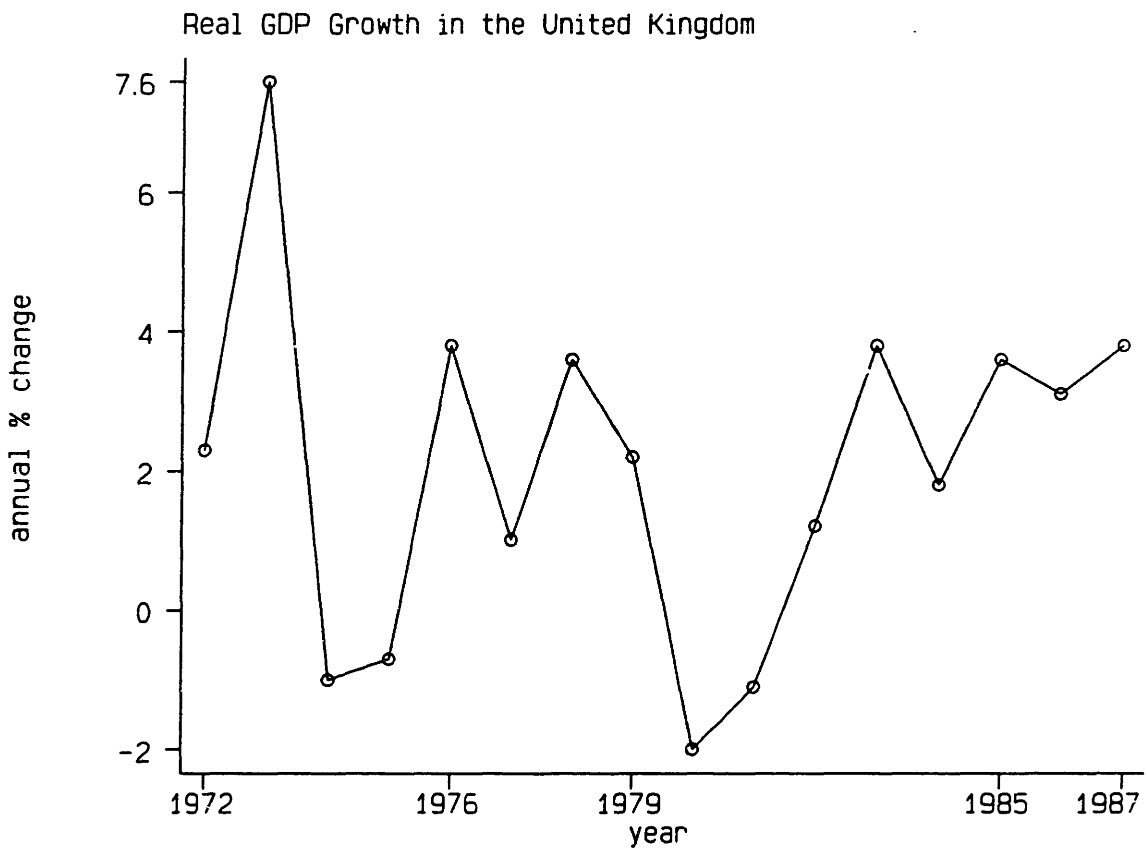
Real GDP Growth in the United Kingdom
7.6
6
4
2
0
-2
annual % change
1972
1976
1979
1985
1987
year

Table 1

PRODUCT LIFE CYCLES

IBM AND DEC COMPUTERS
(Units Shipped per Year)

Model	DFI	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
IBM Medium Size																								
360	1965	818	1965	3234	1851	878	685	166																
370/1	1971							450	1790	2618	1167	90												
370/2	1976												30	2100	1380	20								
4321, 4331 4341 (25 models)	1979															425	5125	4110	3890	1580	1210	400		
system 38	1980																1500	1990	2250	2270	2405	2200	1880	1300
4361, 4381 series	1984																				3100	3600	2400	1500
9370	1987																							1900
IBM Large Size																								
360/50	1965	2	45	142	135	184	131																	
370	1971							490	555	463	410	435	210	220	50									
3031, 32	1978														330	630	330							
3033s	1981																	65	80					
3083	1983																			850	1000	310	70	
3090	1987																							70

Model	DFI	68	69	70	71	72	73	74	75	76	78	79	80	81	82	83	84	85	86	87
DEC Medium Sized																				
1040/50	1967	35	53	31	25	35	17	12	21	10										
1060/70	1972					3	9	18	35	45	10	20								
2040/50	1976									25	85	45	15							
2020	1978										60	65	50	20	15	10	10			
2060	1979											30	95	56	44	25	15			
VAX																				
11/780	1978										200	400	800	990	3310	3100	2700	2200	400	180
11/750	1980												25	660	1510	2505	4600	2200	560	170
11/782	1982														35	95	60			
11/785	1984																260	1600	500	100
8600/8650	4/85																	900	730	730
8800	1/86																		65	250
8300	1/86																		250	550
8200	1/86																		1150	1650
8500	6/86																		420	780
8700	8/86																		65	320

Source: International Data Corporation, Framingham, MA, PIC Data File.

DFI = Date First Introduced

Note: Models have been grouped into families such that each model shown is a distinct new product, with substantively different features, and not simple permutations on a given product.

TABLE 2

OCCUPATIONAL EMPLOYMENT

1900 - 50
TOTAL NONFARM ECONOMY[1]
(shares of total employment)

	1900	1910	1920	1930	1940	1950
M, P&T, S	25.6	25.0	24.3	27.5	27.0	25.3
C	5.3	8.3	11.5	11.9	12.4	12.8
Manual and Service	69.1	66.7	64.2	60.6	60.3	61.9
MANUFACTURING (shares of production employment)						
Craft, et. al.[2]	55	49	48	52	49	51
Operatives[2]	30	31	31	30	37	40
Craft, et. al.[3]	44	37	37	40	39	42
Operatives[3]	38	38	37	37	45	48

1950-70
MANUFACTURING
(shares of total employment)

M, P&T, S	12.7	16.7	17.8
C	11.0	12.2	12.5
P,S	76.3	71.1	69.7
(shares of production employment)			
Craft, et. al.	26.4	28.7	29.2

Definitions:

M, P&T, S = Managerial, Professional and Technical, and Sales
C = Clerical
P,S = Production and Service
Craft et. al. = Craftsmen, foremen and kindred workers
Total production employment includes craft et. al., operative and kindred workers, and laborers.

Notes:

[1] Sectoral data are not available for the full period 1900-50 for the broad occupation groups, so total nonfarm economy data are displayed. However, roughly half of the manual and service category is accounted for by manufacturing.

[2] It is not possible to distinguish what portion of employment in certain craft occupations (e.g. carpenters) is in the construction versus the manufacturing sector. Therefore, this row includes craft employment in both the construction and manufacturing sectors. See also note 3 below.

[3] This row exlcudes employment in construction craft occupations.

Source: Kaplan, David L. and M. Claire Casey, "Occupational Trends in the United States: 1900 to 1950," Working Paper No. 5, U.S. Bureau of the Census, 1958; U.S. Bureau of the Census, Occupation by Industry, 1950, 1960, 1970.

TABLE 3

**EMPLOYMENT SHARES BY SKILL GROUP
PRODUCTION WORKERS**

Industry	1977	1980	1983	1986	1986/1977
Fab. Metals (34)					
S	.244	.253	.324	.329	1.35
SS	.289	.297	.384	.380	1.31
U	.467	.450	.291	.289	0.62
Machinery (35)					
S	.354	.356	.448	.455	1.29
SS	.434	.399	.363	.347	0.80
U	.212	.245	.189	.198	0.93
Elec. Mach. (36)					
S	.291	.275	.285	.282	0.97
SS	.233	.380	.374	.385	1.65
U	.476	.346	.341	.330	0.69
Transport (37)					
S	.332	.346	.367	.368	1.11
SS	.274	.365	.334	.321	1.17
U	.394	.289	.299	.310	0.79

Note:

S = skilled, defined by Standard Vocational Training Code of 7 or higher;
SS = semi-skilled, defined by SVT of from 4 to 6;
U = unskilled, defined by SVT of 3 and below.

Source: U.S. Dept. of Employment, Bureau of Labor Statistics, Occupational Employment Statistics, various issues; Dictionary of Occupational Titles; and author's calculations.

TABLE 4

PRODUCTION EMPLOYMENT
(millions)

	1977	1980	1983	1986
SIC 34	1.19	1.16	1.01	1.06
SIC 35	1.37	1.52	1.15	1.18
SIC 36	1.20	1.25	1.12	1.08
SIC 37	1.33	1.19	1.07	1.23
Total	5.09	5.12	4.35	4.55
% skilled	30.8	31.0	35.8	36.1

Source: U.S. Dept. of Labor, Bureau of Labor Statistics, Occupational Employment Statistics, various issues.

TABLE 5

EMPLOYMENT SHARES BY BROAD OCCUPATIONAL GROUPS

Industry	1977	1980	1983	1986
Fab. Metals (34)				
M,P&T,S	13.6	15.0	15.4	15.2
C	9.3	9.8	9.3	10.1
P,S	76.3	75.3	75.3	74.7
Machinery (35)				
M,P&T,S	22.3	24.4	27.3	28.6
C	12.7	13.3	14.2	13.2
P,S	64.3	62.3	58.5	58.2
Elec. Mach. (36)				
M,P&T,S	22.9	25.9	27.7	32.4
C	11.7	12.3	12.1	12.0
P,S	64.9	61.7	60.2	55.6
Trans. Eq. (37)				
M,P&T,S	18.4	23.3	26.2	27.4
C	8.7	9.7	10.3	9.7
P,S	72.3	66.9	63.5	63.0

Note:

M,P&T,S = Managerial, Professional and Technical, and Sales
C = Clerical
P,S = Production and Service

Source: U.S. Dept. of Labor, Bureau of Labor Statistics, Occupational Employment Statistics, various issues.

TABLE 6

EMPLOYMENT SHARES AND WAGES FROM THE CPS
1973-85

YEAR	SKILLED	UNSKILLED	SKILLED/UNSKILLED WAGES
1973	.26	.74	1.32
1974	.27	.73	1.31
1975	.29	.71	1.29
1976	.28	.72	1.30
1977	.27	.73	1.30
1978	.27	.73	1.30
1979	.28	.72	1.31
1980	.31	.69	1.33
1981	.31	.69	1.25
1982	.30	.70	1.29
1983	.26	.74	1.29
1984	.28	.72	1.26
1985	.28	.72	1.35

Note: A redefinition of occupations in 1983 makes the 1973-82 shares non-comparable with the subsequent figures.

Source: May Current Population Survey, annually from 1973-85.

TABLE 7

LABOR DEMAND ESTIMATION
CPS DATA, 1973-85
(standard errors in parentheses)

Variable	OLS (1)	OLS (2)	IV (3)	IV (4)	OLS (5)	OLS (6)
α	.22 (.02)	.051 (.025)	.509 (.276)	.081 (.068)	.272 (.144)	.032 (.027)
β_1(time)	.0033 (.0014)	.0042 (.0018)	.0043 (.0020)	.0041 (.0018)	.0040 (.0017)	.0044 (.001)
β_2(newdef)	-.0426 (.0143)	-.0467 (.0141)	-.0644 (.0239)	-.0422 (.0172)	-.0536 (.0144)	-.0494 (.014)
$\beta_3 \ln(w_s/w_m)$	-	-	.248 (.259)	-	.0166 (.0383)	-
$\beta_4 \ln(w_s/w_u)$	-	-	-.233 (.284)	-.095 (.195)	.0424 (.053)	.0590 (.038)
β_5(UR)	.0067 (.0028)	.0036 (.0033)	.0011 (.0045)	.0026 (.0040)	.0033 (.0034)	.0042 (.003)
$\beta_6 \ln(KS)$	-	-	.0659 (.035)	-	.0464 (.0273)	-
N	13	260	260	260	260	260

Note: the dependent variable is the share of skilled workers in total production employment. The coefficients on the 19 industry dummies are excluded from the table. Instruments are given in the text.

Sources:

employment and wage data: May CPS, 1973-85;
industry output deflators: National Income and Product Accounts, implicit price deflators by industry; B.E.A. Survey of Current Business;
KS: constant dollar capital stock per production worker, by industry, BEA Fixed Reproducible Tangible Wealth in the United States.

TABLE 8

DECOMPOSITION OF RELATIVE WAGE CHANGES BY EDUCATION AND EXPERIENCE[1]: 1979 - 1986

Education	source of change: Composition[2]	Within[3]	Growth[4]	Total
Men: experience 1-5				
8-11	-3.5	-13.4	-2.5	-19.7
12	-4.4	-10.3	-1.5	-17.2
16	1.0	5.9	2.1	8.5
Men: experience 6-10				
8-11	-2.4	-13.6	-2.2	-19.0
12	-2.9	-5.1	-1.0	-10.0
16	2.7	8.7	2.0	13.4
Men: experience 11-25				
8-11	-0.8	-5.9	-1.9	-9.0
12	-0.9	-3.9	-0.6	-6.0
16	1.7	2.1	1.6	5.4
Men: experience 26-35				
8-11	-1.0	-4.1	-1.5	-7.2
12	-0.1	2.2	-0.2	1.7
16	1.4	3.8	1.5	6.8
Women: experience 1-5				
8-11	-4.1	-9.9	-0.4	-14.5
12	-2.4	-1.8	2.2	-2.6
16	2.5	8.1	4.1	14.6
Women: experience 6-10				
8-11	-2.9	-4.8	-0.5	-8.1
12	-2.7	3.1	2.2	2.0
16	4.3	11.0	4.0	19.5
Women: experience 11-25				
8-11	-2.8	5.5	-0.5	2.2
12	-0.6	8.1	2.0	9.6
16	2.9	10.0	4.3	17.5
Women: experience 26-35				
8-11	-1.5	4.1	-0.1	2.7
12	-0.7	7.0	2.0	8.4
16	1.0	8.9	4.3	14.7

Notes:

1 Wage changes are measured relative to that for all white males
2 Wage changes as a result of employment shifts across 45 two-digit SIC industries
3 Wage changes within industries
4 Secular wage growth

Source: Murphy, 1989 NBER Labor Studies Conference mimeo; based on March 1980 and 1987 C.P.S. Annual Demographic Supplements.

TABLE 9

VOCATIONAL QUALIFICATIONS IN MANUFACTURING: BRITAIN (1974 - 78) AND GERMANY (1978)

Industrial group		Employment in each industry as percentage of total economy	Persons with stated qualification levels as percentage of labour force in each industrial group		
			Univ.	Intermediate[1]	None[2]
All mfg	B	31.8	3.3	28.7	68.0
	G	33.8	3.5	60.8	35.7
Food, drink, tobacco	B	3.0	2.0	21.2	76.8
	G	2.5	1.7	60.1	38.2
Petro Prod	B	0.2	6.0	39.8	54.1
	G	0.1	6.5	72.2	21.4
Chem	B	1.8	9.1	28.5	62.4
	G	2.4	7.5	62.5	30.0
Metal Mfr	B	1.8	2.7	27.0	70.3
	G	2.0	2.3	61.2	36.5
Engineering, vehicles and metal-working trades	B	14.9	3.8	34.0	62.2
	G	16.7	4.4	63.4	32.2
Textiles	B	1.9	2.0	17.9	80.2
	G	1.9	1.6	47.5	50.9
Leather	B	0.2	0.0	17.2	82.8
	G	0.2	0.8	49.1	50.1
Clothing and footwear	B	1.9	1.1	15.0	83.9
	G	1.3	0.9	51.0	48.1
Bricks pottery, etc	B	1.1	2.5	21.1	76.4
	G	1.1	1.8	55.9	42.3

TABLE 9 (continued)

VOCATIONAL QUALIFICATIONS IN MANUFACTURING: BRITAIN (1974 - 78) AND GERMANY (1978)

Industrial group		Employment in each industry as percentage of total economy	Persons with stated qualification levels as percentage of labour force in each industrial group		
			Univ.	Intermediate[1]	None[2]
Timber furniture, etc	B	1.1	0.9	32.7	66.3
	G	2.1	0.9	62.0	37.1
Paper and printing	B	2.4	3.3	33.3	63.4
	G	2.0	3.2	63.5	33.3
Other mfr	B	1.6	2.2	20.8	77.0
	G	1.3	2.5	53.9	43.6

Notes:

1 In Britain, includes both time-served and non-examined apprenticeships.

2 For Britain, this group consists mainly (82%) of those reporting no vocational qualification; others have lower, but non-vocational qualification. For Germany, this group consists mainly of those who have not taken or have failed, the apprenticeship final examinations.

Source: Prais (1981a); from General Household Survey, 1974 - 78 in Britain, and Microzensus, 1978 in Germany.

TABLE 10

NUMBERS RECEIVING CRAFT QUALIFICATIONS IN MANUFACTURING INDUSTRIES: BRITAIN (1979) AND GERMANY (1977) (thousands)

Industry	Britain[1]	Germany[2]
Food and drink	0.6	7.2
Chemicals	0.4	5.2
Metals and mechanical engineering	22.9	47.5
Instrument engineering	0.6	3.9
Electricians and electrical engineering	15.8	35.4
Vehicles	14.9	24.8
Textiles, clothing, leather & footwear	2.2	7.9
Timber, furniture	3.3	10.0
Paper and printing	1.2	3.6
Other manufacture	0.1	0.7
Total manufacturing	62.1	146.3

Notes:

[1]Britain: City and Guilds Part II awards;
[2]Germany: Berufsschule final examinations.

Source: Prais (1981a)

TABLE 11

EMPLOYMENT SHARES BY SKILL GROUP IN GERMAN INDUSTRY 1960-87 (% of total production employment)

Industry	SKILL GROUPS[1] 1	2	3
Machinery			
1960	56	31	13
1969	56	31	13
1978	62	28	11
1982	65	25	10
1985	67	24	9
1987	68	24	8
Elec. Mach			
1960	31	38	31
1969	33	33	32
1978	35	32	33
1982	39	31	30
1985	38	30	32
1987	39	30	31
Metal Working			
1960	44	35	20
1969	45	34	21
1978	49	31	19
1982	51	32	17
1985	50	32	18
1987	51	32	17

Notes:

[1] Skill groups are defined as follows:
1) apprenticeship certification or equivalent
2) less than apprenticeship certification but more than six months training
3) six months or less training

Source: Statistiches Bundesamt, Fachserie 16, Riehle 2.1, various years

TABLE 12

EMPLOYMENT SHARES
UNITED KINGDOM
1973-85

Year	Mechanical Eng.			Elec. Eng.			Vehicles		
	S/P	M/T	S/T	S/P	M/T	S/T	S/P	M/T	S/T
1973	.60	.32	.35	.28	.33	.17	.45	.26	.30
1974	.58	.33	.34	.28	.32	.17	.45	.26	.30
1975	.59	.33	.35	.32	.35	.19	.46	.27	.30
1976	.59	.33	.35	.32	.34	.19	.45	.27	.30
1977	.58	.34	.34	.31	.34	.19	.46	.26	.31
1978	.60	.34	.35	.31	.35	.19	.46	.26	.30
1979	.59	.34	.35	.32	.35	.19	.46	.26	.31
1980	.45	.33	.30	.23	.40	.14	.34	.29	.24
1981	.48	.35	.31	.25	.42	.14	.37	.30	.26
1982	.47	.38	.29	.25	.41	.15	.39	.31	.26
1983	.48	.35	.31	.24	.41	.14	.39	.32	.27
1984	.48	.35	.31	.25	.41	.15	.40	.32	.27
1985	.48	.35	.31	.24	.42	.14	.40	.32	.27
1987	.47	.35	.31	.24	.43	.14	.40	.34	.26

Note:

S/P = Craftsmen in occupations normally entered by apprenticeship or equivalent training, divided by total production employment;
M/T = Managerial, administrative, technical and clerical occupations, divided by total employment;
S/T = as above, except total employment is the denominator.

Source: Department of Employment Gazette, various issues.

TABLE 13

RELATIVE WAGES BY OCCUPATIONAL GROUP FOR BRITISH MALE MANUAL WORKERS SELECTED INDUSTRIES 1974-80

Year	Engineering		Shipbuilding & Marine Engineering		Chemicals
	S/SS	S/L	S/SS	S/L	C/GW
1974	1.09	1.39	-	-	-
1975	1.08	1.33	1.22	1.07	1.05
1976	1.07	1.30	1.19	1.06	1.06
1977	1.07	1.31	1.22	1.08	1.05
1978	1.08	1.31	1.22	1.08	1.06
1979	1.11	1.31	1.20	1.07	1.07
1980	1.12	1.32	1.19	1.06	1.07

Note: Occupational groups as defined in Table 15, except for chemicals where GW = general workers = SS + L. Engineering includes mechanical and electrical engineering, shipbuilding, vehicles and metal goods n.e.c.

Source: Department of Employment Gazette, Table 5.5, July 1981.

TABLE 14

RELATIVE WAGES AND EMPLOYMENT SHARES IN THE UNITED KINGDOM
Data from the New Earnings Survey

Occupational Group	1976	1979	1985	1987
Mechanical Engineering				
Relative Wages				
14/15	1.02	1.03	1.01	1.04
14/17	1.39	1.17	1.16	1.16
Employment				
Total (1976=1)	1.0	.97	.94	.87
14/15	6.19	5.79	6.59	6.31
14/17	6.15	6.19	7.95	7.99
Electrical Engineering				
Relative Wages				
14/15	1.04	1.04	1.13	1.11
14/15.1	1.12	1.15	1.20	1.24
14/17	1.18	1.18	1.24	1.20
Employment				
Total (1976=1)	1.0	1.01	.89	.75
14/15	2.55	2.54	3.16	2.93
14/15.1	9.9	7.9	7.6	7.3
14/17	4.67	4.50	5.55	5.78
Vehicles				
Relative Wages				
14/15	1.02	1.03	1.01	1.02
14/15.1	1.03	1.08	1.07	1.04
14/17	1.12	1.12	1.13	1.17
Employment				
Total (1977=1)	1.0	1.01	.78	.67
14/15	3.49	3.41	3.45	3.49
14/15.1	11.97	10.96	14.0	12.59
14/17	6.67	7.07	6.14	6.24

Notes:
Relative wages are ratios of group medians;
14 = Processing, Making, Repairing and Related (Metal and Electrical);
15 = Painting, Repetitive Assembling, Product Inspecting, Packaging and Related;
15.1 = Repetitive Assembling, a component of group 15;
17 = Transport Operating, Materials Moving and Storing and Related.

Source: New Earnings Survey, Section D, 1976, 1979, 1985, 1987; Department of Employment Gazette, Table 1.3, various issues, for total employment by industrty.

TABLE 15

EMPLOYMENT BY OCCUPATION IN THE MOTOR VEHICLES AND PARTS INDUSTRY, 1978-84

Occupation	1978 %	1981 %	1984 %
managerial staff	2.7	3.9	4.7
scientists and technologists	0.6	1.0	1.1
technicians and draughtsmen	4.3	5.2	5.8
administration and professional staff	4.3	5.2	6.2
clerks, office machine operators, secretaries, and typists	7.1	7.0	6.2
supervisors and foremen	4.8	5.0	4.8
craftsmen	14.1	15.7	15.8
operators	36.0 }62.1	37.2 }57.1	55.5
others	26.1	19.9	
numbers	448,466	339,632	261,415

Source: Marsden et. al. (1985) Table 6; from EITB, Sector Profile, Motor Vehicles and Parts Manufacturing, April, 1984.

TABLE 16

EMPLOYMENT AND SHARES BY OCCUPATION[1] IN THE MOTOR VEHICLES AND PARTS INDUSTRY: 1971 AND 1981[2]

Occupation	1971	1981
	(percent)	
manual	80.2	76.0
non-manual	19.4	23.5
managers	2.5	3.7
personnel management, work study	0.6	0.5
mechanical engineers	0.8	1.4
engineers not elsewhere classified and technologists	0.5	2.1
electrical and electronic engineers	0.1	0.1
draughtsmen	1.3	0.9
laboratory assistants and technicians	1.5	0.7
clerks	6.7	5.4
typists, office machine operators	2.8	2.4
foremen	2.5	3.4
apprentices	0.8	
electricians	1.3	1.9
toolmakers	2.3	2.4
sheet metal workers	2.0	1.8
plumbers and pipe fitters	0.3	0.4
welders	3.2	3.4
motor mechanics	1.0	1.8
fitters (maintenance and not elsewhere classified)	7.4	5.9
machine tool setters, operators, turners	14.9	12.8
press, stamp operators, etc.	2.0	0.4
inspectors	4.9	5.9
packers, bottlers	0.8	
repetitive assemblers, etc.	10.5	7.3
labourers	5.2	3.1
security	0.6	0.7
catering	0.6	0.4
% in matched occupations	77.5	70.2

Notes:

[1] The occupations shown are those which could be matched between 1971 and 1981.

[2] Numbers employed in 1979 in SIC (1968:381) were 482,500, and in SIC (1980:35) 491,200 . SIC (1968:381) includes gears and transmission equipment (SIC 1980:326). Source: Census of Production 1979.

Source: Marsden et. al. (1985), Table 7; from UK Census of Population 1971 and 1981, 1971 SIC (1968:387); 1981 SIC (1980:35) motor vehicles and parts.

TABLE 17

INTRA-INDUSTRY TRADE RATIOS
(mean for 1974-84 minus mean for 1958-73)

Industry	Difference
Food	.035
Textiles	.192
Apparel	-.219
Lumber	.267
Furniture	-.085
Paper	.214
Printing & Publishing	.176
Chemicals	.124
Petroleum	-.309
Rubber	.148
Leather	-.089
Stone, Clay & Glass	-.008
Primary Metals	-.041
Fabricated Metals	.242
Machinery	.183
Electrical Machinery	.257
Transport Equipment	.251
Instruments	.133

Source: U.S. Bureau of the Census, U.S. Commodity Exports and Imports as Related to Output, Vols. 64, 65, 71, 72, 84 and 85.

TABLE 18

INDUSTRY RANKINGS
Intra-industry Trade and the Shift to Skilled Workers

Ranking of Industries	
Intra-industry Trade	Shift to Skilled Production Workers
1. Lumber	1. Petroleum
2. Electrical Machinery	2. Paper
3. Transport Equipment	3. Transport Equipment
4. Fabricated Metals	4. Fabricated Metals
5. Paper	5. Textiles
6. Textiles	6. Machinery
7. Machinery	7. Lumber
8. Printing	8. Stone, Clay and Glass
9. Rubber	9. Chemicals
10. Instruments	10. Apparel
11. Chemicals	11. Rubber
12. Food	12. Electrical Machinery
13. Stone, Clay and Glass	13. Food
14. Primary Metals	14. Furniture
15. Furniture	15. Instruments
16. Leather	16. Printing
17. Apparel	17. Leather
18. Petroleum	18. Primary Metals

Note: The miscellaneous and tobacco industries were excluded from both rankings.

Source: see Table 17, and author's calculations from May CPS data.

TABLE 19

ORDER BACKLOGS ANI FINISHED GOODS INVENTORIES
Industry Distributions and Means

Industry	Full Sample		FIFO Sample	
	Share	Mean(OB/FGI)	Share	Mean(OB/FGI)
Food	1.1	1.8	0.4	0.8
Textiles	4.0	1.9	2.6	3.0
Apparel	4.1	1.8	6.0	1.8
Lumber	0.5	1.2	0.7	0.8
Furniture	1.9	3.2	1.9	3.0
Paper	1.0	1.1	-	-
Printing	1.2	1.7	1.0	3.3
Chemicals	2.6	1.3	3.0	1.1
Petroleum	0.3	5.1	0.5	8.5
Rubber	2.5	2.9	2.2	7.3
Leather	1.8	3.9	1.5	5.3
Stone, Clay & Glass	0.8	3.5	1.1	5.1
Primary Metals	3.2	3.7	1.2	2.4
Fabricated Metals	10.6	4.1	7.2	4.2
Machinery	12.1	3.1	10.8	2.8
Electrical Machinery	32.8	7.7	37.6	8.7
Transportation Equip	8.8	7.6	10.5	5.4
Instruments	8.1	4.1	8.5	3.6
Miscellaneous	2.3	2.3	3.4	2.2
	---		---	
	100		100	
DURABLES	.81		.83	
NONDURABLES	.19		.17	

Source: Compustat tapes and authors calculations.

TABLE 20

REGRESSION RESULTS: ORDER BACKLOGS AND FINISHED GOODS INVENTORIES
(t-statistics in parentheses)

Coefficient	Sample (1)	(2)	(3)	(4)	(5)	(6)
α	.331 (1.5)	-	-.2 (.3)	-.34 (.5)	1.43 (4.2)	-.81 (1.6)
β_1*TIME	.017 (2.95)	.011 (2.9)	.016 (2.4)	.009 (1.2)	.020 (2.7)	.020 (2.5)
β_2*TBILL1	.001 (0.0)	.007 (1.1)	.010 (0.7)	.012 (0.7)	.008 (0.5)	.003 (0.2)
β_3*d(CPI)	.028 (3.0)	.021 (4.1)	.028 (2.4)	.019 (1.3)	.033 (2.6)	.036 (2.6)
β_4*UR	-.011 (0.6)	-.017 (1.7)	-.018 (-0.8)	-.022 (-0.9)	.018 (0.7)	.019 (0.7)
β_5*IVM	.009 (0.4)	.020 (1.4)				
β_6*IVM^2	-.001 (0.5)	-.002 (1.4)				
N	4501	4501	3161	2377	2570	2178

where:
TIME=time trend
TBILL1=one-year Treasury Note rate
d(CPI)=annual change in the CPI
IVM=equals one in year of accounting change, and equals 1+n in nth year after change.

samples:
(1) full sample
(2) full sample, fixed effects
(3) excludes observations after change in accounting method
(4) excludes firm if ever change accounting methods
(5) FIFO observations only
(6) FIFO only, excluding any observations after a change in accounting methods

Note: coefficients on industry dummies are suppressed

Source: Compustat and author's calculations.

TABLE 21

INDUSTRY ANALYSIS
(t-statistics in parentheses)

Coefficient	Full Sample Durables	Full Sample Nondurables	FIFO Sample Durables	FIFO Sample Nondurables
α	1.46	-.154	1.21	-.365
	(10.1)	(0.6)	(5.9)	(1.0)
β_1*TIME	.011	.041	.017	.047
	(1.6)	(3.5)	(1.8)	(2.6)
β_2*TBILL1	.010	-.035	.016	-.097
	(0.7)	(1.3)	(0.8)	(2.4)
β_3*d(CPI)	.022	.053	.024	.111
	(2.0)	(2.6)	(1.4)	(3.7)
β_4*UR	-.022	.052	.001	.132
	(1.0)	(1.3)	(0.0)	(2.3)
	3659	842	1805	373
mean(OB/FGI)	5.21	1.98	5.35	2.52

PRODUCTION TO ORDER AND SKILLED WORKERS
Top Industries[1]

Increase in (OB/FGI), FIFO Only Sample	Shift to Skilled Production Workers
Leather	Petroleum
Textiles	Paper[2]
Transport Equipment	Transport Equipment
Fabricated Metals	Fabricated Metals
	Textiles
	Machinery

Notes:

[1]Industries with a significant positive coefficient on the time trend in industry by industry regressions using the respective models.

[2]The FIFO data does not include any paper industry firms.

Source: Compustat and author's calculations.

Appendix A

List of Occupations: New Earnings Survey of the U.K.

The occupations are arranged in 18 main groups. Those in groups I to IX are classified as non-manual with six exceptions, marked with an "m" in groups VII, VIII and IX. These six and all occupations in groups X to XVIII are classified as manual.

GROUP I – MANAGERIAL (GENERAL MANAGEMENT)

- Top managers – national government and other non-trade organisations
- General central, divisional managers – trading organisations

GROUP II – PROFESSIONAL AND RELATED SUPPORTING MANAGEMENT AND ADMINISTRATION

- Judges, barristers, advocates and solicitors
- Company secretaries
- Town clerks and other clerks to local authorities
- Secretaries of trade associations, trade unions, professional bodies and charities
- Accountants
- Estimators, valuers and assessors
- Finance, investment, insurance and tax specialists
- Personnel and industrial relations officers and managers
- Organisation and methods, work study and operational research officers
- Economists, statisticians and actuaries
- Systems analysts and computer programmers
- Marketing and sales managers and executives
- Advertising and public relations managers and executives
- Purchasing officers and buyers
- Property and estate managers
- Librarians and information officers
- Public health inspectors
- Other statutory and similar inspectors
- General administrators – national government
- General administrators – local government
- All other professional and related supporting management and administration

GROUP III – PROFESSIONAL AND RELATED IN EDUCATION, WELFARE AND HEALTH

- University academic staff
- Teachers in establishments for further and higher education
- Secondary teachers
- Primary teachers
- Pre-primary teachers
- Special education teachers
- Vocational/industrial trainers
- Directors of education, education officers, school inspectors
- Social and behavioural scientists
- Welfare workers – social, medical, industrial educational and moral
- Clergy, ministers of religion
- Medical practitioners
- Dental practitioners
- Nurse administrators and nurse executives
- State registered and state enrolled nurses and state-certified midwives
- Nursing auxiliaries and assistants
- Pharmacists
- Medical radiographers
- Ophthalmic and dispensing opticians
- Remedial therapists
- Chiropodists
- Medical technicians and dental auxiliaries
- Veterinarians
- All other professional and related in education, welfare and health

GROUP IV – LITERARY, ARTISTIC AND SPORTS

- Journalists
- Artists, commercial artists
- Industrial designers
- Actors, musicians, entertainers, stage managers
- Photographers and cameramen
- Sound and vision equipment operators
- Window dressers
- Professional sportsmen, sports officials
- All other literary, artistic and sports, including authors and writers

GROUP V – PROFESSIONAL AND RELATED IN SCIENCE, ENGINEERING, TECHNOLOGY AND SIMILAR FIELDS

- Biological scientists and biochemists
- Chemical scientists
- Physical and geological scientists and mathematicians
- Civil, structural and municipal engineers
- Mechanical engineers
- Electrical engineers
- Electronic engineers
- Electrical/electronic engineers
- Production engineers
- Planning and quality control engineers
- Mining, quarrying and drilling engineers
- Aeronautical engineers
- Chemical engineers
- Heating and ventilating engineers
- General and other engineers
- Metallurgists
- All other technologists
- Architectural draughtsmen
- Engineering and other draughtsmen
- Laboratory technicians – scientific and medical
- Engineering technicians and technician engineers
- Architects and town planners
- Town planning assistants, architectural and building technicians
- Quantity surveyors
- Building land and mining surveyors
- Aircraft flight deck officers
- Air traffic planners and controllers
- Ships' masters, deck officers
- Ships' engineers officers
- Ships' radio officers
- All other professional and related in science, engineering and other technologies and similar fields

GROUP VI – MANAGERIAL (EXCLUDING GENERAL MANAGEMENT)

- Production managers, works managers, works foremen
- Engineering maintenance managers
- Site and other managers, agents, clerks of works, general foremen (building and civil engineering)
- Managers – underground mining and public utilities
- Transport managers – air, sea, rail, road, harbour
- Managers – warehousing and materials handling
- Office managers – national government
- Office managers – local government
- Other office managers
- Managers – wholesale distribution
- Managers – department store, variety chain store, supermarket and departmental managers
- Branch managers of shops other than above
- Managers of independent shops (employees)
- Hotel and residential club managers
- Publicans (employees)
- Catering and non-residential club managers
- Entertainment and sports managers
- Farm managers (employees)
- Police officers (inspectors and above)
- Fire service officers
- Prison officers (chief officers and above)
- All other managers

GROUP VII – CLERICAL AND RELATED

- Supervisors of clerks
- Costing and accounting clerks
- Cash handling clerks
- Finance, investment and insurance clerks
- Production and materials controlling clerks
- Shipping and travel arranging clerks
- Records and library clerks
- General clerks and clerks not identified elsewhere
- Retail shop cashiers
- Retail shop check-out and cash and wrap operators
- Receptionists
- Supervisors of typists etc
- Personal secretaries, shorthand writers and shorthand typists
- Other typists
- Supervisors of office machine operators
- Accounting and calculating machine operators
- Key punch operators
- Automatic data processing equipment operators
- Office machine operators not identified elsewhere
- Supervisors of telephonists, radio and telegraph operators
- Telephonists
- Radio and telegraph operators
- m Supervisors of postmen, mail sorters and messengers
- m Postmen, mail sorters and messengers

GROUP VIII – SELLING

- Sales supervisors
- Salesmen, sales assistants, shop assistants, and shelf fillers
- m Petrol pump/forecourt attendants
- m Roundsmen and van salesmen
- Technical sales representatives
- Sales representatives (wholesale goods)
- Other sales representatives and agents

GROUP IX – SECURITY AND PROTECTIVE SERVICE

- Supervisors (police sergeants, fire fighting and related)
- Policemen (below sergeant)
- Firemen
- Prison officers below principal officer
- Security officers and detectives
- m Security guards, patrolmen
- Traffic wardens
- m All others in security and protective service

Groups X to XVIII: manual. A few occupations, prefixed with letter "m" in groups VII, VIII and IX are also classified as manual

GROUP X – CATERING, CLEANING, HAIRDRESSING AND OTHER PERSONAL SERVICE

Catering supervisors
Chefs, cooks
Waiters, waitresses
Barmen, barmaids
Counter hands/assistants
Kitchen porters/hands
{ Supervisors – housekeeping and related
{ Supervisors/foremen – caretaking cleaning and related
Domestic housekeepers
Home and domestic helpers, maids
School helpers and school supervisory assistants
Travel stewards and attendants
Ambulancemen
Hospital/ward orderlies
Hospital porters
Hotel porters
Caretakers
Road sweepers (manual)
Other cleaners
Railmen, stationmen
Lift and car park attendants
Garment pressers
Hairdressing supervisors
Hairdressers
All other in catering, cleaning hairdressing and other personal service

GROUP XI – FARMING, FISHING AND RELATED

Foremen – farming horticulture, forestry
General farm workers
{ Dairy cowmen
{ Pig and poultrymen
{ Other stockmen
Horticultural workers
Domestic gardeners (private gardens)
Non-domestic gardeners and groundsmen
Agricultural machinery drivers/operators
Forestry workers
Supervisors/mates (fishing)
Fishermen
All other in farming, fishing and related

GROUP XII – MATERIALS PROCESSING (EXCLUDING METAL)

(Hides, textiles, chemicals, food, drink and tobacco, wood, paper and board rubber and plastics)
Foremen – tannery production workers
Tannery production workers
Foremen – textile processing
Preparatory fibre processors
Spinners, doublers/twisters
Winders, reelers
Warp preparers
Weavers
Knitters
Bleachers, dyers and finishers
Burlers, menders, darners
Foremen – chemical processing
Chemical, gas and petroleum process plant operators
Foremen – food and drink processing
{ Bread bakers (hand)
{ Flour confectioners
Butchers and meat cutters
Foremen – paper and board making
{ Beatermen, refinermen – paper and board making
{ Machinemen, dryermen, calendermen, reelermen – paper and board making
Foremen – processing – glass, ceramics, rubber and plastics etc
Glass and ceramic furnacemen and kilnmen
Kiln setters
Masticating millmen – rubber and plastics
Rubber mixers and compounders
Calender and extruding machine operators – rubber and plastics
Man-made fibre makers
Sewage plant attendants
All other in materials processing (other than metal)

GROUP XIII – MAKING AND REPAIRING (EXCLUDING METAL AND ELECTRICAL)

(Glass ceramics, printing paper products clothing footwear woodworking, rubber and plastics)
Foremen – glass working
Glass formers and shapers
Glass finishers and decorators
Foremen – clay and stone working
{ Casters and other pottery makers
{ Cutters shapers and polishers – stone
{ Foremen – printing
{ Foremen – paper products making
{ Foremen – bookbinding
Compositors
Electrotypers stereotypers
Other printing plate and cylinder preparers
{ Printing machine minders (letterpress)
{ Printing machine minders (lithography)
{ Printing machine minders (photogravure)
{ Printing machine assistants (letterpess lithography and photogravure)
Screen and block printers
Bookbinders and finishers
Cutting and slitting machine operators (paper and paper products making)
Foremen – textile materials working
{ Bespoke tailors and tailoresses
{ Dressmakers
{ Clothing cutters and makers (measure)
{ Other clothing cutters and makers
{ Coach trimmers
{ Upholsterers mattress makers
Milliners
Furriers
Hand sewers and embroiderers
Linkers
Sewing machinists (textile materials)
Foremen – leather and leather substitutes working
{ Boot and shoe makers (bespoke) and repairers
{ Leather and leather substitutes cutters
{ Footwear lasters
{ Leather and leather substitutes sewers
{ Footwear finishers
Foremen – wood working
{ Carpenters and joiners (construction sites and maintenance)
{ Carpenters and joiners (ship and stage)
{ Carpenters and joiners (other)
{ Cabinet makers
{ Case and box makers
Wood sawyers and veneer cutters
Woodworking machinists (setters and setter operators)
Other woodworking machinists (operators and minders)
Patternmakers (moulds)
Labourers and mates to woodworking craftsmen
Foremen – rubber and plastics working
Tyre builders
Moulding machine operators/attendants (rubber and plastics)
Dental mechanics
All other in making and repairing (excluding metal and electrical)

GROUP XIV – PROCESSING, MAKING, REPAIRING AND RELATED (METAL AND ELECTRICAL)

(Iron, steel and other metals engineering (including installation and maintenance vehicles and shipbuilding)
Foremen – metal making and treating
{ Blast furnacemen
{ Furnacemen (steel smelting)
{ Other furnacemen – metal
Rollermen (steel)
{ Moulders and moulder/coremakers
{ Machine moulders shell moulders and machine coremakers
{ Die casters
Metal drawers
Smiths, forgemen
Electroplaters

GROUP XIV – PROCESSING, MAKING, REPAIRING AND RELATED (METAL AND ELECTRICAL) – *(continued)*

Annealers, hardeners, temperers (metal)
Foremen – engineering machining
Press and machine tool setters
Roll turners roll grinders
Other centre lathe turners
Machine tool setter-operators
Machine tool operators (not setting up)
Press and stamping machine operators
Automatic machine attendants/minders
Metal polishers
Fettlers/dressers
Foremen – production fitting (metal)
Toolmakers, tool fitters markers out
Precision instrument makers
Metal working production fitters (fine limits)
Metal working production fitter-machinists – (fine limits)
Other metal working production fitters – (not to fine limits)
Foremen – installation and maintenance – machines and instruments
Machinery erectors and installers
Maintenance fitters – non-electrical plant and industrial machinery
Knitting machine mechanics (industrial)
Motor vehicle mechanics (skilled)
Other motor vehicle mechanics
Maintenance and service fitters – aircraft engines
Watch and clock repairers
Instrument mechanics
Office machinery mechanics
Foremen – production fitting and wiring (electrical/electronic)
Production fitters – electrical/electronic
Production electricians
Foremen – installation and maintenance (electrical/electronic)
Electricians – installation and maintenance (plant and machinery)
Electricians – installation and maintenance (premises/ships)
Telephone fitters
Radio television and other electronic maintenance fitters and mechanics
Cable jointers and linesmen
Foremen/supervisors – metal working – pipes sheets structures
Plumbers, pipe fitters
Heating and ventilating engineering fitters
Gas fitters
Sheet metal workers
Platers and metal shipwrights
Caulker burners, riveters and drillers (constructional metal)
General steel workers – shipbuilding and repair
{ Steel erectors
{ Scaffolders stagers
{ Steel benders, bar benders and fixers
Welders – skilled
Other welders
Foremen – other processing making and repairing (metal and electrical)
Goldsmiths silversmiths and precious stone workers
Engravers and etchers (printing)
Coach and vehicle body builders/makers
Aircraft finishers
Maintenance and installation fitters – mechanical and electrical
Setter operators of woodworking and metal working machines
{ All other skilled in processing making and repairing (metal and electrical)
{ All other non-skilled in processing making and repairing (metal and electrical)

GROUP XV – PAINTING, REPETITIVE ASSEMBLING, PRODUCT INSPECTING, PACKAGING AND RELATED

Foremen – painting and similar coating
Painters and decorators
Pottery decorators
{ Coach painters
{ Other spray painters
French polishers
{ Foremen – product assembling (repetitive)
{ Foremen – product inspection
Repetitive assemblers (metal and electrical goods)
Inspectors and testers (skilled) – metal and electrical engineering
Viewers – metal and electrical engineering
Foremen – packaging
Packers, bottlers, canners fillers
All other in painting repetitive assembling, product inspecting packaging and related

GROUP XVI – CONSTRUCTION, MINING AND RELATED NOT IDENTIFIED ELSEWHERE

Foremen – building and civil engineering not identified elsewhere
Bricklayers
Fixer – walling masons
Plasterers
Floor and wall tilers, terrazzo workers
Roofers and slaters
Glaziers
Railway trackmen and platelayers
{ Asphalt and bitumen road surfacers
{ Other roadmen
Concrete erectors/assemblers
Concrete levellers/screeders
General builders
{ Sewermen (maintenance)
{ Mains and service layers and pipe jointers (drainage gas oil water)
Waste inspectors (water supply)
Craftsmen's mates and other builders labourers not identified elsewhere
Civil engineering labourers
Foremen/deputies – coalmining
Face-trained coalmining workers
Tunnellers
All other in construction, mining quarrying well drilling and related not identified elsewhere

GROUP XVII – TRANSPORT OPERATING, MATERIALS MOVING AND STORING AND RELATED

{ Foremen – ships, lighters and other vessels
{ Foremen – rail transport operating
{ Foremen – road transport operating
{ Deck and engine room hands (sea-going)
{ Bargemen lightermen boatmen tugmen
Locomotive drivers motormen
Secondmen (railways)
Railway guards
Railway signalmen and shunters
Bus inspectors
Bus and coach drivers
Heavy goods drivers (over 3 tons unladen weight)
Other goods drivers
Other motor drivers
Bus conductors
Drivers mates
Foremen – civil engineering plant operating
Mechanical plant drivers/operators – earth-moving and civil engineering
Foremen – materials handling equipment operating
Crane drivers/operators
Fork lift and other mechanical truck driver/operators
Foremen – materials moving and storing
Storekeepers warehousemen
Stevedores and dockers
Furniture removers
Warehouse market and other goods porters
Refuse collectors/dustmen
All other in transport operating materials moving and storing and related not identified elsewhere

GROUP XVIII – MISCELLANEOUS

Foremen – miscellaneous
Electricity power plant operators and switchboard attendants
Turncocks (water supply)
{ General labourers – engineering and shipbuilding
{ Other general labourers
All other in miscellaneous occupations not identified elsewhere

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