Microelectronics, Automation and Employment in the Automobile Industry

Edited
by
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Preface by Ajit S. Bhalla
Foreword by Aubrey Silberston

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ILO Preface

The question of the relationship between microelectronics and employment is no longer very new. What is novel, however, is the growing interest in empirical examination of the impact of microelectronics on employment at micro and macro levels. The current controversy about the employment impact of microelectronics stems partly from the lack of adequate empirical investigations.

This ILO study, edited by Mr Susumu Watanabe, a senior staff member of the ILO World Employment Programme, is, in our view, the first systematic comparative country analysis to be focused on a particular industry. It is in the class of empirical studies which are based on both primary and secondary data. The choice of the automobile industry is governed by the fact that this industry is one of the major users of micro electronic equipment such as NC machines and robots. The volume contains case studies of five major automobile-producing countries (Brazil, France, Italy, Japan and the United States), as well as information on the automobile industry in the Federal Republic of Germany, Sweden and the United Kingdom. It should serve a useful purpose for identifying and filling gaps in our knowledge about the precise nature of the impact, positive or negative, that new technologies are likely to have on employment.

This book is one of the results of an ongoing research project within the ILO Technology Programme, which is funded partly by the ILO regular budget and partly (e.g. Chapter VII on Brazil) by SAREC (Sweden). The project is designed to examine the impact of new technologies on employment and on the international division of labour in both industrialized and developing countries. Apart from studies on various industries the employment implications of the use of microelectronics in the service sector (e.g. banking and insurance) are also being examined. It is intended to extend research further in the direction of an analysis of the differential impact of new technologies on different groups of countries.

A. S. BHALLA
Chief, Technology and Employment Branch
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The impact of microelectronics on industrial structure and on employment is a subject of great current interest. The present book considers this subject in detail as it affects the automobile industry. It focuses particularly on the often-repeated claim that microelectronic technology will diminish employment in industry. It shows that this claim is not proven as yet, and it explains clearly why this is so.

It is interesting to look at the present study from a historical point of view, and for me it is of particular interest to compare it with the book on the motor industry that George Maxcy and I published in 1959. We presented a picture of the industry during the 1950s, before the European industries had got into their stride after the war and when the Japanese industry was so unimportant that there was not a single reference to it in our index. The balance of output between countries has changed very greatly since then. In one major respect, however, our book is much less out of date than in its treatment of comparative levels of output. I refer to its treatment of costs of production, because we were trying to measure, for the first time, the economies of large-scale production in this industry. We discussed the use of automatic transfer machines in the mass production of automobiles and we stressed the importance of such techniques in enabling substantial economies of scale to be reaped. Our book was translated into Japanese very quickly. Susumu Watanabe argues in Chapter III of the present book that our conclusions had a major impact on the Japanese automobile manufacturers by convincing them of the importance to this industry of the economies of large-scale production.

We dealt with what Mr Watanabe refers to as ‘fixed automation’. Since we wrote, the microelectronic revolution has occurred, and the resulting ‘flexible automation’ has become an important feature of the motor industry. It takes the form of robots, numerically controlled (NC) machine tools and computer-aided design and manufacturing (CAD/CAM). The main preoccupation of the present book is to gauge the impact of these developments on employment in the industry, and it is interesting that it reaches the conclusion that the adverse effects have so far been less than had been feared.

One of my own main interests is in how far modern developments have affected the optimum scale of production in the automobile industry. At first sight, one would imagine that the increased flexibility of modern techniques—for example the ability to reprogramme robots without great
difficulty—would have led to a reduction in the optimum scale of production. Yet we have very large scales of output in the Japanese industry, which has embraced all of these microelectronic techniques. What is the truth of the matter? Mr Watanabe’s book goes into this question at some length. It stresses that we still cannot be absolutely sure of the answer, because the rate of diffusion of the new techniques has been a good deal slower than was envisaged in the early 1970s. What is suggested, however, is that for the largest scales of output, ‘fixed automation’ is still needed to give the greatest possible savings in costs. What ‘flexible automation’ may do is to make possible greater economies at medium scales than were previously thought feasible. Swedish experience helps to confirm this finding.

This book points out that there has been rapid adoption in the automobile industry of two techniques originating from Japan: the ‘just-in-time’ or ‘Kamban’ system and the ‘QC (quality control) circle’. But although these techniques have had a great impact, only the first has been much affected by microelectronic developments and neither is principally concerned with the effects on the production process of the new microelectronic techniques. Mr Watanabe points out that flexible manufacturing systems are in fact still rare in the automobile industry, and that various technical and economic constraints have tended to slow down the process of their full adoption. There have certainly been labour-saving effects where the new technology has been introduced, but they have in practice been smaller than suggested by theoretical calculations. This is partly because automobiles have become more complicated, which suggests that labour saving would have been greater if comparisons had been made on the basis of unchanged vehicle types. A very interesting suggestion is that the new techniques have assisted the movement towards greater complication: they have had a ‘work-amplifying’ effect, as the study puts it.

A striking finding is that the labour-saving effects of the new technology have been more limited in Japan than elsewhere. A higher rate of automation had been achieved there than in other countries by the late 1970s, through investment in ‘fixed automation’, so that very high levels of productivity had already been obtained. Even so, the flexibility of the robot has been appreciated much less in Western Europe and North America, where robots have often been employed as fixed automation equipment, than it has in Japan.

It is clear from this example, and from others given in the course of the book, that the microelectronic revolution is still at an early stage in the automobile industry, and that much technical (and social) adaptation will need to occur if the full benefits of the new technologies are to be obtained. Fixed automation is still very prevalent, and this is one reason why Japan gains so much from her large scale of production. When the new methods are fully assimilated, however, they will certainly increase flexibility, and are likely to reduce the optimum scale of production. Even so, this is likely to remain an industry where large-scale production is necessary for the lowest possible costs to be achieved.
What I have said gives only a taste of the interest of this volume. I am pleased that my former Cambridge pupil, Susumu Watanabe, together with his collaborators, has produced so interesting and timely a work.

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March 1986
Notes on the Contributors

Bruce T. Allen is Professor of Economics at Michigan State University. His recent research interests are in the areas of competition, monopoly and related public policies. He has published numerous articles in professional journals, has edited *MSU Business Topics* and is a contributing reviewer for the *Wall Street Review of Books*.

Aldo Enrietti is a researcher at the University of Torino.

Piero Ferri is Professor of Economics at the University of Bergamo. He is the author of *I Salari nella Economia Post-Keynesiana* (1978). His main contributions are in the field of macro-economics and labour economics.

Warren Seering is Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology. He is currently conducting research on robotic system performance at the MIT Artificial Intelligence Laboratory. He has served as a consultant to several large robotics companies in the area of design of high-performance manipulators and has lectured on this topic throughout Europe, Japan and the United States.

Francesco Silva is Professor of Industrial Organisation at the University of Bergamo. His publications include *Il Mercato Italiano dell'Auto nel Contesto Europeo* (with M. Grillo and M. Prati) (1982).

José Ricardo Tauile is Vice-Director of the Instituto de Economia Industrial, the Universidade Federal do Rio de Janeiro. He is also a consultant to labour unions, government and private and international agencies on economic and social implications of microelectronics-based automation. He has published many works on the subject.

Glossary

AFRI: Association Française de Robotique Industrielle.

ANFAVEA: National Association of Motor Vehicle Manufacturers, Brazil.

Block-built machines: special-purpose machines built of standardized blocks and units of blocks which can accommodate changes in the product specifications by switching the relevant piece of block or unit.


BRA: British Robot Association.

CAD/CAM: computer-aided design/computer-aided manufacturing.

Cam: a part of a wheel or other component in machinery, grooved, toothed or otherwise adapted to convert circular into reciprocal or variable motion.

CIG: Cassa Integrazione Guadagni. Italian system of lay-off financially supported by the Government.

CKD: completely knocked down.

CNC (computer numerical control): a means of controlling machinery by programmed instructions from a small computer or microprocessor.

Downtime: time a machine or plant spends in non-productive fashion, e.g. waiting for materials, maintenance and tool changes.

EDM: electric discharge machine.

FIEV: Fédération des Industries des Equipements pour Véhicules, France.

Fixed automation: automation based on special-purpose machines or transfer machines designed for specific tasks related to a product of one particular specification.

Flexible automation: automation based on microelectronic machinery, which can be adapted to modifications of product specifications.

FMS (flexible manufacturing system): a system of machines for flexible automation.
Glossary

IC (integrated circuit): an electronic circuit made by fabricating components such as resistors, capacitors and transistors on a single piece of a semiconductor material, usually silicon.

JAMA: Japan Automobile Manufacturers Association.
JAPIA: Japan Auto-Parts Industries Association.
JAW: Japan Automobile Workers' Union.
JIRMA: Japan Industrial Robot Manufacturers Association.
JMTBA: Japan Machine Tool Builders Association.

Just-in-time system: a mode of work organization within a plant or among different firms designed to minimize stockpiling of parts and components in any part of the production processes.

Kamban system: a term popularly used as a synonym of ‘just-in-time system’.

KD: knocked down.

Manipulator: motion device used mainly for material handling tasks.

MC (machining centre): a kind of numerically controlled multiple-purpose machine tool which is equipped for automatic tool change and different types of machining work, such as milling, boring, drilling, etc.

Microprocessor: an integrated circuit that can serve as the processing unit for a digital computer.

MITI: Ministry of International Trade and Industry, Japan.

NC (numerical control): means of controlling equipment by instructions stored as numbers on punched cards, tapes, computer memory, etc.

Pneumatics: type of control system based on valves actuated by compressed air.

PSA: Peugeot Société, Anonyme.

PUMA: Programmable Universal Machine for Assembly. A robot jointly developed by General Motors and Unimation.

QC (quality control) circle: grouping of workers aimed at their active participation in quality control and in efforts for improving productivity and work environments.

R & D: Research and development.

RIA: Robotic Industries Association, formerly Robot Institute of America.

RNUR: Régie Nationale des Usines Renault.

RVI: Renault Véhicules Industriels.
SCARA: Selective Compliance Assembly Robot Arm.

SEI: Special Secretariat of Informatics, Brazil.

Special-purpose machines: machines designed for one or a set of tasks to produce a product of a particular specification.

Stopper: a simple device attached to automatic machines for the purpose of interrupting their operation whenever something starts going wrong.

Transfer machine: a line of special-purpose machines linked with devices for automatic transfer of workpieces.

UAW: United Automobile Workers. The largest and single most important trade union in the automobile industry of the United States.

Uptime: time spent in productive operations by a machine.
CHAPTER I

Introduction

Susumu Watanabe

1 THE PURPOSE OF THE STUDY

In the forefront of today's technological advances, microelectronic machinery—such as robots, numerically controlled (NC) machine tools and computer-aided design and manufacturing (CAD/CAM)—has an image of being most capital-intensive and labour-saving. People tend to take it for granted that the diffusion of this new technology will reduce employment, and associate it with the high, and often still rising, unemployment rates in industrialized countries. Causes of the unemployment problem are multiple, however: slow recovery from the worldwide economic depression triggered off by the oil crisis of 1973-74, the baby boom of the 1950s and 1960s in North America and western Europe, considerably increased female labour force participation rates, etc.1 While some of these factors do not attract much attention, the accelerated pace of microelectronic innovation since the late 1970s is too visible to escape notice, partly because of frequent coverage of the subject by the media. But to what extent is the new technology really responsible for the current unemployment problem?

Various authors have attempted to assess the labour-saving or job-displacement effects2 of microelectronics at different levels of economic activities and with different degrees of empiricism.3 Some studies published in the 1970s were extremely pessimistic, predicting enormous job losses as a result of the diffusion of the new technology.4 Probably because of an improved information base, more recent authors take less alarmist views. The most widely discussed study in this context is that of Leontief and Duchin (1984), which concludes that the United States will have a labour shortage problem by the year 2000.5 Nevertheless, pessimistic views have not disappeared altogether, especially among European workers.6

Microelectronic innovation takes place simultaneously with many other changes, and it is difficult to isolate its effects. This is part of the explanation for the conflict of views. Apart from this, assessments of the overall employment impact in the future differ largely because of variations in the underlying assumptions regarding (a) the likely rate of diffusion of the technology, (b) the prospect of demand for the products and (c) the possibility of 'compensation effects'.
The likely rate of diffusion of the new technology depends on the aggregate size of potential areas of application and on constraints on its application. Lack of experience tended to give rise to overoptimistic expectations regarding the former and underestimation of the latter. In Sweden, the Computers and Electronics Commission reports: 'In 1972 experts claimed that by the end of the decade there would be 25,000 IRb (= industrial robots) installed in Sweden. The actual outcome was a growth rate of about 40 per cent per year on average and an installed IRb-stock of nearly 1000 units (1979) . . . it is a good example of how the barriers to the wide diffusion of a new technology are often underestimated.'

Regarding the prospect of demand, a constant level of output is often assumed. Studies on the ex-post impact at the industrial, company or lower level rarely mention what happened to the overall production level and the product mix. A typical and frequently cited example is the following statement concerning the experiences of the watchmaking industries of Switzerland and the Federal Republic of Germany: ' . . . microelectronics caused a reduction by some 46,000 employees in the mid-seventies in Switzerland. The number of employees in the German watchmaking industries has slumped by some 40 per cent'. As Peitchinis points out, in reality responsibility rests with the failure of the industries to apply the new technology, and the resultant loss of markets.

'Compensation effects' can arise from a number of sources. For example, the new technology may increase the demand for the products of the user industries, either in the domestic market or in the export market, by lowering the production costs and improving the quality of the products, and add to the national effective demand by stimulating investment in microelectronics-based machinery. Generally speaking, studies resulting in a conclusion of big job losses neglect or regard as insignificant the compensation mechanisms, while those ending with more optimistic assessment have faith in adjustment mechanisms.

These problems in assessing the (potential) employment impact at relatively high levels of aggregation are compounded by difficulties in determining the labour-saving effect at and below the firm level. For example, a study in Japan found that one worker tended between 0.6 and 3.5 NC machine tools at nine plants investigated, the average machine-worker ratio being 1.85. Another study discovered that each robot saved anything between less than 0.5 and more than five workers, 40 per cent of the sample (211 plants) being concentrated in the range of 0.5—1 worker. In both cases one needs to know the conditions existing prior to the introduction of the new equipment (for example the previous machine-man ratios) and changes taking place simultaneously with the microelectronic innovation.

It is therefore not surprising if Cooper and Clark (1982) conclude that 'perhaps the main impression one gets from these studies is that any conclusion is possible in the current state of knowledge'. Leontief and Duchin (1984), whose optimistic conclusion partly depends on their assumptions,
note the need for a more reliable empirical data base in improving their model and its practical value.

The present volume is intended to contribute to the building up of such a data base and to a more realistic assessment of the employment impact of the microelectronic technology by means of case studies of the automobile industry of different countries. More specifically, this volume explores the following questions:

(a) To what extent and in what production processes has the microelectronic technology been applied?
(b) For what purposes or reasons is it used?
(c) How has its application affected employment at the levels of production lines, individual firms and the industry as a whole?
(d) What are the causes of the differences in the labour-saving effect of the new technology among different countries and among firms within the same country?
(e) What are the major constraints on the diffusion of the new technology, and what is the prospect for the future?

To the extent that this is possible we will examine these issues with respect to different groups of firms (assemblers, major component manufacturers and small subcontractors) and different groups of workers. An inquiry into these subjects will almost inevitably touch upon the impact of the new technology on skill requirements, work organization and industrial relations. However, we will limit our discussion on the latter subjects to a minimum, partly for the purpose of keeping the focus of our exercise clear and partly because a number of organizations and researchers' groups have studied them specifically.16

The automobile industry was chosen as the object of our investigation for the following reasons. First, in most countries this is one of the largest users of microelectronic machinery, especially NC machines and robots.17 Second, employment in this industry has declined considerably in major automobile-producing countries since the late 1970s, when the diffusion of NC machine tools and robots began to accelerate.18 Third, this industry accounts for significant percentages of the national industrial production and employment in these countries (Table 1) and therefore its employment trend has been causing serious concern.

A few assessments of potential employment effects at the industrial level have been published in the United States.19 Sporadic attempts have been made in different automobile industries to evaluate the ex-post employment effect of the new technology at plant or production line level. To our knowledge, however, there has been no multi-country research on the employment impact with respect to one particular industry. What is even more important, one gains an impression that the existing studies on the subject are based on the experiences at major companies. It is our hope that a comparative study of different automobile industries and of different firm groups
Table 1: World automobile production in 1983, and the share of the automobile industry in the national industrial output and employment in the early 1980s

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (in '000 vehicles)</th>
<th>Employment (in '000 workers)</th>
<th>Share in the national industrial total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Passenger cars</td>
<td>Buses and trucks</td>
</tr>
<tr>
<td>World total</td>
<td>39 727</td>
<td>29 670</td>
<td>10 057</td>
</tr>
<tr>
<td>Japan</td>
<td>11 111</td>
<td>7 151</td>
<td>3 960</td>
</tr>
<tr>
<td>United States</td>
<td>9 205</td>
<td>6 781</td>
<td>2 424</td>
</tr>
<tr>
<td>Germany, Fed. Rep. of</td>
<td>4 170</td>
<td>3 877</td>
<td>293</td>
</tr>
<tr>
<td>France</td>
<td>3 335</td>
<td>2 960</td>
<td>375</td>
</tr>
<tr>
<td>USSR</td>
<td>2 120</td>
<td>1 250</td>
<td>870</td>
</tr>
<tr>
<td>Italy</td>
<td>1 575</td>
<td>1 395</td>
<td>180</td>
</tr>
<tr>
<td>Canada</td>
<td>1 502</td>
<td>955</td>
<td>547</td>
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<tr>
<td>United Kingdom</td>
<td>1 289</td>
<td>1 045</td>
<td>244</td>
</tr>
<tr>
<td>Spain</td>
<td>1 288</td>
<td>1 141</td>
<td>147</td>
</tr>
<tr>
<td>Brazil</td>
<td>896</td>
<td>772</td>
<td>124</td>
</tr>
<tr>
<td>Sweden</td>
<td>396</td>
<td>344</td>
<td>52</td>
</tr>
</tbody>
</table>

<sup>a</sup>1982; <sup>b</sup>1981; <sup>c</sup>1980.

within each industry will help discover facts and issues hitherto neglected in
the literature.

2 PLAN OF THE VOLUME

This volume contains case studies of four out of the five largest automobile-
producing market economy countries (Japan, the United States, France and
Italy) and the largest automobile-producing country in the Third World, that
is, Brazil (cf Table 1). As the authors of these chapters are all economists, a
discussion on the technicalities of microelectronic machinery, especially the
robot and the NC machine tool, by an engineer may be enlightening. This is
found in Chapter II. Unfortunately we were unable to secure a study from the
Federal Republic of Germany. To reduce this gap, some information from
that country is included in the present chapter as well as in Chapter VIII,
which contains a synthesis of our findings. These two chapters also contain
some information on Sweden, the world's most intensive user of robots.

Of the whole range of microelectronic production technology, our studies
will be concerned mainly with robots and NC machine tools, although
occasional references will be made to designing technology of CAD/CAM,
office automation and product technology in the form of electronic auto-parts
and components. Probably the most serious omission is the reprogrammable
controller which enhances efficiency in plant management. This omission is
due largely to the methodological difficulty in isolating its effect from that of
the organizational rationalization in general.

Our country case studies are based on first-hand information obtained
through company visits and second-hand material from official and other
sources. Starting with a common framework of the study, each stresses
different aspects of the industry and the new technology. This is a reflection of
specific conditions in the individual countries as well as different degrees of
accessibility to desired information.

In Chapter II, Seering discusses from the engineer's viewpoint how robotics
and NC machine tools have evolved, what are their technical advantages and
limitations vis-à-vis human workers and conventional machines and what one
might be able to anticipate from them in the future. In doing so, he explains
why the rate of diffusion and the areas of application of these machines have
been much more limited than people tended to expect when they appeared.
Finally, the author suggests that the impact of the new technology on work
environment largely depends on how it is used.

In Chapter III, Watanabe first shows, on the basis of industrial level data,
that a process of rapid productivity increase in the Japanese automobile
industry ended before the advent of NC machine tools and robots, and
explores main sources of productivity increase during earlier periods. By
subsequent analysis of micro-level information obtained through visits to
some 60 firms, he verifies the validity of conclusions drawn from the first part
and sheds light on the motivation and mode of application of the new
machinery, with reference to different firm groups. Saving of labour was not a main objective, and the new technology tended to induce an increase in the amount of work put into each vehicle.

Allen starts his analysis in Chapter IV by describing a number of major changes that took place in the North American automobile market after the mid-1960s. One of their consequences has been an increased dialogue between the automobile manufacturers and trade unions, which explains the smooth diffusion of microelectronic production technology in the industry, although it has been used primarily to reduce labour cost. So far, the diffusion of NC machine tools has been wide but dispersed, and consequently their impact on employment has been very slight. The author estimates, however, that 5000–7000 robots installed in the automobile industry of Canada and the United States may have caused displacement of a maximum of 14 000 jobs by early 1985. On the basis of projections worked out by other scholars, moreover, he argues that the employment level in 1990 might be 15 per cent lower than the 1980 level if the production level remained the same.

In Chapter V, Watanabe first reviews the trends and structure of the French automobile industry and notes a considerable decline in the employment level. The use of NC machine tools and robots appears modest, especially among component manufacturers and subcontractors. The Renault and Peugeot groups have been enthusiastic about microelectronic innovation, but organizational rationalization and other changes have also been important. The final section deals with the Government's programmes for encouraging microelectronic innovation and for helping to cope with redundancy resulting from modernization and organizational rationalization.

Largely relying on the data supplied by FIAT, Silva, Ferri and Enrietti in Chapter VI argue that the rapid decrease in employment in the Italian automobile industry was primarily due to organizational rationalization, although labour saving was a primary purpose of robotization of FIAT's plants. Changes in industrial relations and personnel policy had a crucial influence in carrying out this rationalization programme. The authors' inquiries at fifteen component producers discovered differences in the motivation of microelectronic innovation and in its labour-saving effect among different product groups.

Tauile in Chapter VII shows that the diffusion of robots and NC machine tools is still very limited in the Brazilian automobile industry. Subsidiaries of the multinational companies introduced them essentially as a means of internationalization of their operation, that is, for the purpose of manufacturing internationally interchangeable components. Labour saving is a minor consideration, since wage rates are still low in this country. Where NC machines are introduced, however, Tauile estimates that each of them will replace three to five workers on conventional machines, while creating 1.5 new jobs, per shift.

Chapter VIII synthesizes findings in the earlier chapters and explores causes of differences in the labour-saving effect observed in different coun-
tries and within each country. It is also pointed out that existing assessments tend to overestimate the employment effect in two ways. On the one hand, they neglect differences in the mode of application of the new technology among different firm groups (above all, the rate of capacity utilization). On the other, one important element of the compensating effects is neglected, namely, the ‘work-amplifying effect’ of the new technology. Finally, a number of promising areas of further research are identified.

Before we proceed to the next chapter, it is convenient for the analysis in the subsequent chapters to discuss certain aspects of the automobile industry and microelectronic technology, looking somewhat more closely at the issues to be explored in the volume.

3 THE AUTOMOBILE INDUSTRY AND THE NEW TECHNOLOGY

Figure 1 shows the trends of production (cars, buses and trucks), employment and output (number of vehicles produced) per worker in the automobile industry of the five largest producer countries among the market economies and Brazil. One extremely interesting aspect of the diagram is that only in Japan and France did each worker produce substantially more vehicles in 1983–84 than in 1972–73, namely, just before the first oil crisis. Superficially this gives one an impression that productivity of labour did not increase in other countries during this period. Moreover, in Japan, output per worker stopped rising and the number of hours worked per vehicle increased after 1980, which the Japanese refer to as ‘the first year of the robot era’. This apparently contradicts the popular notion that ‘. . . the introduction of microelectronic technology will mean that it will take less time to produce existing products . . . partly because production lines can be automated or speeded up, but mainly because the number of components in a product—and thus the time taken to assemble it—can be greatly reduced by the incorporation of chips . . .’. It also goes against frequent press reports of cuts in the workforce at automobile assembly plants and in the time required for a given task at different workposts of the automobile industry. What explains this gap?

This question is all the more intriguing because, apart from microelectronic innovation, many other changes have been taking place in this industry to improve productivity. In the United Kingdom, for example, it has been reported that the ‘decline in employment is a direct effect of decreased production but also of increased productivity, involving the closure of uneconomic plants, reductions in overmanning and the installation of modern labour-saving equipment’. Jones (1983) attributes one-third of the job losses in the British automobile industry between 1979 and 1981 (from 489 000 to 377 000) to plant closures which took place as part of the industry’s rationalization programme.
Microelectronics, Automation and Employment in the Automobile Industry

Production (No. of vehicles)
Output per worker
Employment (No. of workers)

Japan

United States

Federal Republic of Germany
Figure 1  Trends of automobile production, employment and output per worker, 1972–84 (1973 = 100). Sources: See Annex 1.
remained more or less constant since 1979 while automobile production declined and investment grew rapidly (Annex 2). The company had installed 1102 robots by the end of 1983, when the country had a total of 4800 (about 40 per cent in the automobile industry). The amount of work per vehicle increased considerably as a result of replacement of the ‘Beetle’ with the higher value-added Golf. Volkswagen produces robots and other capital goods which are used by its plants, as well as energy equipment. The company also diverted considerable numbers of workers for retraining. These changes may have been influenced partly by the pressure from its Works Council to maintain the size of its workforce. Since it recruited as many as 28 500 workers between mid-1984 and the end of 1985 as the automobile production recovered, however, it is difficult to believe that labour hoarding was a main explanation for the decline in output per worker.

An analysis of the situation in the Swedish automobile industry is extremely difficult because of the internationalization of its operations. In the case of the Volvo group, which had about 350 robots in April 1985, the (global) number of vehicles produced per worker did not increase until 1982. It grew, however, remarkably in 1983 (Annex 3). Available data do not permit a judgement as to whether this was due to technological factors or to the jump in the production level which a company representative attributed to a major success in their sales campaign in the United States market.

These pieces of evidence make one suspect that the employment effect of the new technology may have been exaggerated and that some important compensating factor(s) may have been neglected. How, and which factor(s)? This is another key issue that the present volume is intended to explore.

In this connection, it is important to note the change that took place in the international automobile market during the 1970s. Until the beginning of this decade, North American and European car makers specialized in certain types and sizes of cars and had a relatively easy time competing mainly in terms of product design and ‘styling’ rather than by price and performance. Since then the situation has changed:

The types of automobiles demanded across the developed world converged dramatically. This was particularly true in the United States, whose predominant ‘very large’ automobile had been in a size class of its own. Suddenly every world manufacturer was a potential threat to every other manufacturer in a largely integrated world market. Worse, from the producers’ standpoint, it was a buyer’s market, because the slump in demand due to the slumping world economy created excess capacity for the world auto industry in aggregate. Some national industries (notably in Japan and parts of Europe) were able to produce cars of unchallenged quality or at substantially lower cost, or both, and so a dramatic export surge developed as the less competitive national industries reeled under a flood of imports in addition to a deep slump in the overall market.

An increased competition will require greater efforts not only at cost savings but at better adaptation of products to users’ tastes. In such high levels of consumer affluence as prevail in industrialized countries, the latter can be
more important. At the Longbridge plant of British Leyland which the present author visited in May 1985, a company representative explained that robotization of the plant was aimed at the solution of the problem of quality control arising from poor quality of labour. It is possible that economists' preoccupation with price competition has resulted in overemphasis on the labour-saving aspect of the new technology and underestimation of its implications for quality improvements. This is a hypothesis we will explore in subsequent chapters.

Investment decisions are made on the basis of a wide range of considerations. Labour saving is only one of them, and it often arises because of problems of supply of labour. This may be illustrated with reference to Volvo's experience. When the present author visited Volvo in April 1985, the automobile division of the company had about 300 robots in Sweden. About 80 per cent of this total were installed in two plants. At one plant each robot was estimated to save two workers in two shifts and require a total of 0.5 worker in maintenance and programming. The main objectives of robotization at these plants were as follows:

<table>
<thead>
<tr>
<th>Plant A</th>
<th>Plant B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot welding</td>
<td></td>
</tr>
<tr>
<td>1. Flexibility</td>
<td>1. Work environment</td>
</tr>
<tr>
<td>1. Regular quality of work</td>
<td>2. Better quality of work</td>
</tr>
<tr>
<td>3. Working environment</td>
<td>3. Higher overall productivity, including</td>
</tr>
<tr>
<td>(boring work)</td>
<td>that of capital</td>
</tr>
<tr>
<td>3. Labour saving</td>
<td></td>
</tr>
<tr>
<td>Arc welding</td>
<td></td>
</tr>
<tr>
<td>1. Flexibility</td>
<td>1. Regular quality of work</td>
</tr>
<tr>
<td>1. Work environment</td>
<td>2. Labour saving</td>
</tr>
<tr>
<td>Painting</td>
<td>3. Work environment</td>
</tr>
<tr>
<td>1. Work environment</td>
<td></td>
</tr>
<tr>
<td>1. Better/regular quality of work</td>
<td></td>
</tr>
<tr>
<td>3. Labour saving</td>
<td></td>
</tr>
<tr>
<td>3. Energy saving</td>
<td></td>
</tr>
<tr>
<td>Material handling</td>
<td></td>
</tr>
<tr>
<td>1. Labour saving</td>
<td></td>
</tr>
<tr>
<td>2. Work environment</td>
<td></td>
</tr>
</tbody>
</table>

At Plant B it was stressed that all the listed objectives were interrelated. This plant suffered from high absenteeism (about 25 per cent), high labour turnover and difficulty in recruitment. In order to reduce or circumvent these problems, labour needed to be saved and work had to be made more attractive to workers ('job humanization'). If workers could be made happier with their work, the quality of their work would improve and at the same time productivity would increase. The auto-component division of the same
company had installed about 110 NC machine tools by the end of 1984 as compared with 60 in 1975 and about 80 in 1980. The short lead time was the primary consideration in applying these machines, while labour saving was not important because conventional machines in transfer lines were more productive. Apart from the overall cost savings arising from the short lead time, quality of work, flexibility and work environment were mentioned as the factors influencing the investment decisions. This factory also had a problem of recruitment: there was a constant shortage of 80–100 workers.

Three out of the five parts and component manufacturing firms visited in this country were using microelectronic machinery. They all mentioned flexibility as the main consideration: these machines were economical in dealing with relatively small batches (production runs) of work they received from car makers. Car makers' severe quality standards provided another common motivation. While one firm stated that no significant labour-saving effect was observed partly because they did not use the machines full time, two others mentioned that such machines were necessary to overcome the problem of recruitment of workers. This was either because of the absolute shortage of labour in their region or because people were just not interested in the kinds of job involved.

The country studies included in this volume also confirm a great diversity of motives for microelectronic innovation. They also show, broadly, inter-country differences in the motivation and corresponding variations in the employment impact.

4 TECHNOLOGY, SCALE AND ORGANIZATION OF THE INDUSTRY

Work in the automobile industry involves seven main production processes: casting, forging, machining, stamping, welding, painting and final assembly. Heat treatment is required here and there. Recently a new process of plastic moulding has been added as a result of substitution of engineering plastics for steel in certain components. The major processes and related components at an assembler's plant may be illustrated as in Figure 2, although the actual plant layout and products vary from case to case.

Apart from the suppliers of basic materials (e.g. iron and steel, and glass), parts (e.g. bolts and nuts, and other small metal pieces) and components (e.g. tyres and car radios), who are usually classified as firms belonging to other industries, the automobile industry consists of three broad groups of firms: assemblers, component manufacturers and subcontractors. The assemblers produce the chassis and some other key components and assemble the vehicles. The component manufacturers develop functional components in collaboration with an assembler and produce them for the latter. The subcontractors produce or process parts and simpler components according to the specifications given by an assembler or a component manufacturer. They may work for other subcontractors. Usually the firms in the third category are smaller than those in the second, but the crucial difference between the two
Introduction

Purchose of ports
- Tyres
- Electrical parts
- Glass
- Bearings
- Nuts, bolts, etc.
- Others

Purchase of raw materials
- Pig iron
- Ordinary steel
- Speciality steel
- Non-ferrous metals
- Others

Purchase of processed materials
- Cost pig iron
- Cost non-ferrous metals
- Forged materials

Inspection

Costing
  - e.g. Cylinders
  - Brake drums
  - Transmission housings

Forging
  - e.g. Crankshafts
  - Axle shafts
  - Gears

Stamping
  - e.g. Door panel
  - Body shell

Heat treatment

Body assembly

Machining

Painting

Engine assembly

Transmission assembly

Axle assembly

Chassis assembly

Body mounting

Final assembly

Final adjustment and inspection

Finished car

Figure 2  Processes of automobile production: an illustrative example. Adapted from a chart in Nissan Motor Co.: Data File 1983 (Tokyo), p. 20.

groups is that the second group normally has a technological capacity to develop its product while the third group does not have such capacity. Different assemblers rely on their component manufacturers and subcontractors to different degrees. For example, one assembler produces crankshafts and axleshafts in-house, while another relies on component manufacturers for the supply of such items. It follows that one cannot compare different assemblers' productivity simply in terms of the number of vehicles produced per worker.

Nor are such figures on the industrial level quite comparable internationally: the coverage of the statistics on the auto-parts manufacturing sector is different from country to country and it is also usually incomplete. In fact, different sources give different employment figures, as noted in Chapters IV and V. This is the explanation for the gaps between some of the data presented in Table 1 and those in subsequent chapters. If one sticks to one series of data, however, one can use them for an intertemporal analysis of the individual countries, which is what is attempted in this volume.
A classical presentation of the relationship between the scale of production, the organization of work and the choice of technique in the conventional automobile industry is found in Maxcy and Silberston (1959). As the scale of output of any standardized product grows, costs can be reduced by altering work organization from the batch production method to the flow production method and by mechanization. 'When the volume of output is very large and the product standardized, it becomes worthwhile to adopt flow production, i.e. to arrange machines in sequence, so that a whole series of operations can be carried out one after the other. At smaller scales of output, it would not pay to do this, as it would be necessary to rearrange the machines when the type of work to be carried out was changed, and this would have to be done at frequent intervals. Batch production has therefore to be employed', grouping the same kind of machines together. The flow production method reduces wasteful movement of workpieces and increases the scope for mechanization of material handling. With a very small scale of production, general-purpose machines are used, which can be made semi-automatic by attaching simple devices for somewhat larger lot sizes (production runs). When the scale of production becomes large, special-purpose machines designed for the particular work are introduced. They are not flexible but are often able to work much faster than general-purpose machines by performing several operations at once, and possibly replacing several general-purpose machines, or to do work which could not be done at all by the latter. At a very large scale of production, such machines are organized into lines of transfer machines:

At very large scales of output, it pays to introduce special-purpose machines into the line, and to mechanise extensively. The logical outcome of this is the automatic transfer machine, the principal form which 'automation' takes in the motor industry. Machines of this type are, in effect, automatic flow production lines. They work to a time cycle, and incorporate arrangements for automatically transferring the part to be processed from one 'station' to the next one, when machines at each station have carried out their work on the part. The obvious advantage of machines of this type is that they save labour, but they bring with them several other important advantages.

Subsequently the concept of transfer machines spread to other processes such as stamping, moulding and welding. Technological progress has also made it possible to integrate a number of 'stations' into a single machine.

The relationships among the three variables described above are clearly reflected in Table 2, which illustrates the situation in the Japanese automobile industry around 1970. The actual location of the border lines in the table depends on the nature of the product and the quality and idiosyncracies of the workers, as well as on industrial relations. For example, automatic-transport or material-handling devices may be introduced at a smaller scale of production in the case of heavier workpieces than with lighter ones, but workers' tolerance of the weight will vary according to the sex, age, social environment, etc. It has been observed that in the United States and Western Europe the batch production method is more usual than the flow production method.
Table 2: Production scale, work organization and technology in the conventional machining process

<table>
<thead>
<tr>
<th>Production capacity (in '000 units/month in two shifts)</th>
<th>Production method</th>
<th>Typical type of machinery</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Batch method</td>
<td>General-purpose machines</td>
<td>Layout by type of machines</td>
</tr>
<tr>
<td>3</td>
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<td></td>
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<tr>
<td>4</td>
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<td>5</td>
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<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Flow method</td>
<td>Special-purpose machines</td>
<td>Modification of general-purpose machines into semi-special-purpose machines by jigs and fixture</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
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<td></td>
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<tr>
<td>10</td>
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<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Automatic flow method</td>
<td>Transfer machines</td>
<td>Combined use of special-purpose machines and transport devices such as conveyors and chutes</td>
</tr>
<tr>
<td>13</td>
<td></td>
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<td></td>
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<tr>
<td>14</td>
<td></td>
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<td></td>
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<tr>
<td>15</td>
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</tr>
</tbody>
</table>


which prevails in Japan. Since the 1950s the Japanese firms have aimed at a maximum use of the flow production method, for example by training multi-skilled workers who will tend a number of different kinds of machines (Section 2, Chapter III). In North America and Western Europe, multi-skilled workers are today's 'emerging requirements' (see Chapters IV and V). There also seem to be some problems of industrial relations that impede the spread of the flow production method in these regions.

Since many special-purpose machines are specific to one particular set of operations on a particular part of the vehicle, they have to be scrapped when the design of that part of the vehicle is changed. Therefore they are suitable for very large scales of output but they do not meet differentiated demand patterns and requirements of frequent model changes. In this sense, automation based on special-purpose machines and transfer machines is 'fixed automation'.

The appearance of the microprocessor (one-chip computer) in 1974 permitted the development of lower-cost and more reliable numerically con-
Microelectronics, Automation and Employment in the Automobile Industry
trolled (NC) machine tools and robots. Compared with the conventional machines, these machines have the following advantages: (1) greater flexibility in switching recurrently from one kind of work to another to deal with different shape designs, batch sizes, materials and tolerances; (2) shorter lead times, for example because preparation of cams is unnecessary; (3) smaller inventories, because small batches become economical with these machines and can often be produced for individual orders rather than for inventory; and (4) easier control of the unit cost, delivery date and quality, because managerial and more experienced people can programme the work and because the machinery will follow the instructions automatically, eliminating room for human errors in interpretation and communication. Moreover, NC machine tools are capable of handling highly complicated or delicate shape designs that the conventional machine tools could not produce or could do so only at high costs.

Generally speaking, NC machine tools are considered to be the most efficient for recurrent production of small and medium-sized batches. Except where the shape of the product (e.g. dies) is too difficult for conventional machines, general-purpose machines are more economical for very small lots, especially for once-for-all production of one or a few pieces. For very large lots, special-purpose machines are preferred, partly because the time required for metal-cutting work can be longer with NC machines. Similarly, the robot is suitable for handling medium-sized batches:

Robots fit best in a production operation that makes neither too few nor too many of a single product . . . people are still more flexible than robots. Manufacturing that involves very small production runs with frequent changes can be more effective with a few willing workers than with a reprogrammable robot. However, as the volume of a product increases, the cost of human labour will increase linearly . . . the added shift production using the robot actually brings the effective cost per unit down. The robot, however, does have a speed limitation. . . . As the volume continues to grow, if the same part is to be made in quantities of millions continuously over several years, then high speed, special purpose automation will prove to be the most cost effective. Such situations exist in the manufacturing of parts that are used in automobile transmissions for many models over several years.

In terms of both the scale of production and the productivity of labour, therefore, microelectronic production machinery can be regarded as an intermediate technology. This may be illustrated in a simplified form as in Figure 3, where the economically viable range of batch size for microelectronic machinery is Q1Q2. The exact location of Q1 and Q2 varies from case to case, depending among other things on the degree of complexity of the work, the size and/or weight of the workpieces and the quality of workers.

Just as special-purpose machines can be organized into a transfer line to achieve an extremely high degree of automation, NC machine tools and robots can be used in a machining cell and flexible manufacturing system (FMS). Thus, the relationship between the scale of production, the organiz-
ation of work and the choice of machinery in the age of ‘flexible automation’ may be illustrated as in Table 3.

Where the small scale of production hitherto precluded firms from automation, microelectronic machinery, especially robots, offers an opportunity for it. This seems to be an important explanation for the Swedes’ enormous enthusiasm for robots which was mentioned earlier. A report of a survey of the Swedish metal engineering industry states\(^{40}\) that ‘in the sample, the flexibility of robots was in most cases exploited to only a minor degree, or not made use of at all, the robot merely serving as fixed automation equipment’.

Table 3: Production scale, work organization and machinery in the microelectronics-based metal engineering industry

<table>
<thead>
<tr>
<th>Lot size (no. of pieces)</th>
<th>Large complex parts</th>
<th>Small simple parts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1–10</td>
<td>10–300</td>
</tr>
<tr>
<td></td>
<td>1–300</td>
<td>300–15 000</td>
</tr>
<tr>
<td>Work method</td>
<td>Piece</td>
<td>Batch</td>
</tr>
<tr>
<td>Machinery</td>
<td>Manual machines</td>
<td>NC machines</td>
</tr>
<tr>
<td></td>
<td>Stand-alone NC</td>
<td>with automated</td>
</tr>
<tr>
<td></td>
<td>machines</td>
<td>part-handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Machining cell</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FMS</td>
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</tbody>
</table>

Adapted from OTA (1984, p. 36), which is based on Machine Tool Task Force: Technology of Machine Tools, October 1980.
A word of warning about the concept of 'robot' is in order. The most widely used definition is that given by the Robot Institute of America (RIA): 'A robot is a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialised devices, through variable reprogrammed motions for the performance of a variety of tasks.' It is adopted by most authors in this volume. The Japan Industrial Robot Association (JIRA) uses a much wider concept, including all of the following automation devices:

1. Manual manipulator: A manipulator that is directly controlled by an operator
2. Fixed-sequence robot: A manipulator which functions following a preestablished sequence which cannot be easily changed
3. Variable-sequence robot: A manipulator which functions following a preset sequence which can be easily modified
4. Playback robot: A manipulator that can repeat any operation after being instructed by a man
5. Numerically controlled (NC) robot: A manipulating robot which receives orders through numeric control
6. Intelligent robot: A robot that can determine the functions required through its sensing and recognitive abilities

According to the RIA definition, the robots include Japanese robots of variable-sequence and above categories. In Chapter III, however, variable-sequence robots are excluded from the concept of 'robots' because major companies interviewed did not regard them as robots. Categories C and D in the French classification broadly correspond to this narrow definition and the 'robots' in Chapter V comprise these two categories.

Finally, in the subsequent chapters frequent references will be made to the *just-in-time system* and *QC (quality control) circle*. The former is intended to minimize stockpiling of parts and components along the assembly line or, ideally, in any part of the production processes, and to save the inventory cost. In order to minimize inventory of parts and components, one needs to secure a regular and even flow of work and enforce a thorough quality control. Implementation of this system often goes with microelectronic innovation: in some cases the first induces the second and in other cases the second encourages the first. The QC circle is a grouping of workers which is aimed at their active participation in quality control and in efforts for improving efficiency and work environments. These systems originate in Japan and they are discussed in some detail in Chapter III.
Annex 1: Trends of automobile production, employment and output per worker in selected countries (1972–84)
(1973 = 100; 1974 = 100 for Brazil)

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>1972</td>
<td>88.8</td>
<td>95.6</td>
<td>92.8</td>
<td>89.2</td>
<td>90.4</td>
<td>98.0</td>
<td>96.6</td>
<td>97.2</td>
<td>100.0</td>
</tr>
<tr>
<td>1973</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>1974</td>
<td>92.5</td>
<td>96.8</td>
<td>95.5</td>
<td>79.4</td>
<td>92.7</td>
<td>84.8</td>
<td>78.5</td>
<td>97.5</td>
<td>80.5</td>
</tr>
<tr>
<td>1975</td>
<td>98.0</td>
<td>94.7</td>
<td>102.7</td>
<td>70.9</td>
<td>85.2</td>
<td>82.9</td>
<td>80.7</td>
<td>90.1</td>
<td>90.3</td>
</tr>
<tr>
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<td>110.7</td>
<td>98.0</td>
<td>112.5</td>
<td>90.7</td>
<td>92.4</td>
<td>98.1</td>
<td>97.9</td>
<td>94.2</td>
<td>104.8</td>
</tr>
<tr>
<td>1977</td>
<td>120.2</td>
<td>99.1</td>
<td>120.5</td>
<td>100.2</td>
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<td>101.0</td>
<td>103.9</td>
<td>98.3</td>
<td>104.7</td>
</tr>
<tr>
<td>1978</td>
<td>130.9</td>
<td>100.5</td>
<td>129.5</td>
<td>101.7</td>
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<td>95.2</td>
<td>106.0</td>
<td>102.2</td>
<td>103.2</td>
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<tr>
<td>1979</td>
<td>141.7</td>
<td>102.6</td>
<td>137.5</td>
<td>90.5</td>
<td>106.0</td>
<td>84.8</td>
<td>107.6</td>
<td>105.8</td>
<td>101.6</td>
</tr>
<tr>
<td>1980</td>
<td>162.1</td>
<td>107.6</td>
<td>150.0</td>
<td>63.2</td>
<td>85.8</td>
<td>73.3</td>
<td>98.2</td>
<td>107.5</td>
<td>91.9</td>
</tr>
<tr>
<td>1981</td>
<td>165.7</td>
<td>110.3</td>
<td>150.0</td>
<td>62.6</td>
<td>84.9</td>
<td>73.3</td>
<td>98.7</td>
<td>105.3</td>
<td>93.5</td>
</tr>
<tr>
<td>1982</td>
<td>160.3</td>
<td>109.7</td>
<td>145.5</td>
<td>54.2</td>
<td>75.5</td>
<td>71.4</td>
<td>102.9</td>
<td>106.4</td>
<td>96.8</td>
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<tr>
<td>1983</td>
<td>168.0</td>
<td>110.1</td>
<td>151.8</td>
<td>72.6</td>
<td>80.7</td>
<td>89.5</td>
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<table>
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<th>France Employment</th>
<th>France Output per worker</th>
<th>Italy Production</th>
<th>Italy Employment</th>
<th>Italy Output per worker</th>
<th>Brazil Production</th>
<th>Brazil Employment</th>
<th>Brazil Output per worker</th>
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<td>107.5</td>
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<td>100.0</td>
<td>100.0</td>
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<td>100.0</td>
<td>102.8</td>
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<td>95.7</td>
<td>100.0</td>
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<td>109.0</td>
<td>111.2</td>
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<td>95.6</td>
<td>92.5</td>
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<td>100.7</td>
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<td>128.0</td>
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<td>110.0</td>
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<td>95.8</td>
<td>110.0</td>
<td>82.2</td>
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<td>85.1</td>
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<td>93.8</td>
<td>90.1</td>
<td>103.8</td>
<td>73.2</td>
<td>92.9</td>
<td>79.1</td>
<td>99.0</td>
<td>103.9</td>
<td>93.3</td>
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<td>95.5</td>
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<td>1984</td>
<td>95.2</td>
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<td>116.3</td>
<td>81.8</td>
<td>75.6</td>
<td>109.6</td>
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</table>

Based on the basic data given in Chapters III–VII. For the Federal Republic of Germany, production data are from Verband der Automobilindustrie: Tatsachen und Zahlen, various years. Employment figures were supplied by the Statistisches Bundesamt.
Annex 2: Production, employment and investment at Volkswagen (inc. Audi/NSU)

<table>
<thead>
<tr>
<th>Year</th>
<th>Production ('000 vehicles) (1)</th>
<th>Employment ('000 workers) (2)</th>
<th>(1)/(2)</th>
<th>Investment (million DM) (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>1720</td>
<td>161</td>
<td>10.7</td>
<td>928</td>
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<td>1974</td>
<td>1359</td>
<td>142</td>
<td>9.6</td>
<td>1313</td>
</tr>
<tr>
<td>1975</td>
<td>1229</td>
<td>118</td>
<td>10.4</td>
<td>594</td>
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<tr>
<td>1976</td>
<td>1436</td>
<td>124</td>
<td>11.6</td>
<td>657</td>
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<tr>
<td>1977</td>
<td>1561</td>
<td>133</td>
<td>11.7</td>
<td>969</td>
</tr>
<tr>
<td>1978</td>
<td>1569</td>
<td>139</td>
<td>11.3</td>
<td>1559</td>
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<tr>
<td>1979</td>
<td>1558</td>
<td>157</td>
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<tr>
<td>1980</td>
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<td>1983</td>
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<td>1984</td>
<td>1474</td>
<td>160</td>
<td>9.2</td>
<td>3332</td>
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</table>

From the company's *Annual Reports*, various years.

Annex 3: Global production and employment in the Volvo Group

<table>
<thead>
<tr>
<th>Year</th>
<th>Production ('000 vehicles) (1)</th>
<th>Employment (2)</th>
<th>(1)/(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>257.5 (181.8)</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>1975</td>
<td>315.5 (174.7)</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>1976</td>
<td>325.0 (174.6)</td>
<td>42 550</td>
<td>7.6</td>
</tr>
<tr>
<td>1977</td>
<td>253.8 (139.4)</td>
<td>40 900</td>
<td>6.2</td>
</tr>
<tr>
<td>1978</td>
<td>287.0 (159.6)</td>
<td>42 950</td>
<td>6.7</td>
</tr>
<tr>
<td>1979</td>
<td>351.5 (189.8)</td>
<td>47 200</td>
<td>7.4</td>
</tr>
<tr>
<td>1980</td>
<td>303.2 (155.9)</td>
<td>46 250</td>
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</tr>
<tr>
<td>1981</td>
<td>320.3 (166.6)</td>
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</tr>
<tr>
<td>1982</td>
<td>356.4 (182.9)</td>
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<td>7.9</td>
</tr>
<tr>
<td>1983</td>
<td>410.1 (198.6)</td>
<td>45 400</td>
<td>9.0</td>
</tr>
</tbody>
</table>

*Note*
The figures in parentheses relate to production in Sweden.


**NOTES**

2. While 'labour saving' may or may not result in elimination of jobs and workers from a given production process, 'job displacement' means actual elimination of jobs.
3. For a fairly comprehensive review of literature on this subject see, for example, Peitchinis (1983), Freeman and Soete (1985) and Kaplinsky (1987).
4. Often quoted examples include unpublished Siemens report (1976), Jenkins and Sherman (1979) and Nora and Minc (1979).
Introduction

5 For a critique on this study based on an input–output table of the United States economy, see Attenborough (1984) and Kaplinsky (1987).

6 For example, ICFTU (1984) maintains that in the light of ‘a number of trade union studies, ... the general view is that the introduction of this [microelectronic] technology has had an overall negative impact on employment’ (p. 35).

7 Swedish Government (1981, pp. 13–14). Doyle and McLennan (1984) argue that the alarmist view ‘is generally based on engineering calculations of the number of jobs that could be taken over by the new machines. This oversimplifies the way in which technology is actually adopted.’ See also Canadian Authorities (1984) for a similar argument.

8 International Metalworkers’ Federation (undated, p. 24).


10 Attenborough (1984, p. 35).

11 Cooper and Clark (1982, p. 126). Optimistic assessments often stress that microelectronic machinery helps increase or maintain employment because without it the firm or industry would lose its market to competitors. This argument is rather weak because cost and quality improvements are also attributable to changes that take place simultaneously in many other domains (design, work organization, production technologies other than microelectronics-based ones, new materials, training, marketing, etc.). It is also loose, in that the result depends on the speed and extent of application of new technology and on the efficiency in its use relative to that of the competitors.


13 As note 12.

14 Cooper and Clark (1982).


17 OECD (1983, p. 42). Various country studies in the present volume also provide evidence to this effect. In the United Kingdom, 1036 out of a national total of 3208 robots installed at the end of 1985 belonged to the automotive industry according to the British Robot Association. The second largest user industry was the rubber and plastics industry (522 robots).

18 See Figure 1. The trend in the United Kingdom has been similar (MacKay, Sladen and Holligan, 1984, p. 4).

19 They are discussed by Allen in Chapter IV.

20 It is estimated that, in 1982, there were 9.6 robots per 10 000 workers in Sweden as compared with 6.6 in Japan, 3.1 in the Federal Republic of Germany, 2.1 in the United States, 1.3 in France and 0.9 in Italy (UN ECE, 1985, p. 46). See also OECD (1983, p. 51).


22 MacKay, Sladen and Holligan (1984, p. 5).


26 In 1974, the company reduced its workforce by 14 300, of whom 7400 received a severance payment ranging from DM5000 to 10 000. Only a few months later,
some of the workers had to be rehired as the demand for the company's cars suddenly picked up. After this experience, stable employment became one of the main objectives of the Works Council of Volkswagen. The cost of negotiated redundancy schemes became prohibitively high, so that it became more attractive for the company to keep workers. In practical terms its policy favoured shorter work hours and labour hoarding during recessions (instead of redundancies) and overtime and even restriction of output (delayed delivery) during peak periods (instead of recruitments) (Streeck (1984) and Windolf (1985, p. 6)).


28 Information supplied by the company during the present author's visit in April 1985.


30 Altshuler et al. (1984, pp. 6–7). The authors of this excerpt argue that this drastic change in the market situation took place after 1979 (i.e. the second oil crisis). This is doubtful. Japanese automobile exports declined after having risen from 2.0 million in 1973 to 6.0 million in 1980 (5.6 million in 1983). Our view is that the change began in 1974 in the wake of the first oil crisis.

31 In a similar context, the experience of Volvo's Kalmar plant has been widely publicized (Agrén and Edgren (1980) and Agrén et al. (1984)).

32 See, for example, note 8, Chapter IV.

33 Maxcy and Silberston (1959, p. 56). Their analysis summarized in the present paragraph proceeds with machining processes in mind. As the authors note (p. 55, footnote 2), the general principles are applicable to most other processes carried out in the industry.

34 As note 33, pp. 56–7. ‘Several other important advantages’ include a much higher rate of utilization of costly machines, savings in the stockpiling space, reduced chance of damaging workpieces, improved quality of work through a closer control of tool life, work location and machine consistency.


36 See OTA (1984, p. 11).

37 To some extent, the 'block-built' type machine tools accommodate changes in work specification by switching some component block(s). They contributed to the initial automation of the Japanese automobile industry (see Toyota Jidōsha Kögyō, 1967, pp. 398–406).


40 In this survey, 91 per cent of the NC machine tools were reprogrammed at least twice a week. Forty per cent of the NC machine tools observed were used for lot sizes 101–1000 pieces, 30 per cent for 11–100 pieces and 23 per cent for 1–10 pieces. In contrast, 42 per cent of the robots observed were used for production runs of 1001–10 000 pieces, 28 per cent for 101–1000 pieces and 25 per cent for over 10 000 pieces (UN ECE (1985, pp. 35–6), quoting Selg and Carlsson (1980)).

41 See UNCTAD (1985, p. 16).

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CHAPTER II

Robotics, Numerical Control and the Computer

Warren Seering

Only the most creative of minds can begin to perceive the magnitude and directions of the influence that computers will have on the manufacturing environment of the future. Mostly in the context of the United States, this essay discusses developments and trends in two areas of technology which are closely tied to advances in computation: robotics and numerical control.¹

1 ROBOTICS

(i) Its evolution

As a field of basic research, robotics is not new. The concept of humanoid machines performing manual tasks has intrigued innovators for hundreds of years. But only in the last two decades has technology allowed inventors to go beyond simple, mechanistic robots. During the late 1960s, researchers at the Stanford Research Institute (now SRI International) developed an experimental robot called SHAKEY that was unique in its ability to both explore and manipulate the environment. It was capable of locating blocks using a television camera and then arranging them into prespecified arrays or stacks. SHAKEY was not noteworthy in its use of new mechanical technology. But it did lead to new methods for programming computers to direct machines.

In 1972 Victor Scheinman, a researcher working in the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology, conceived the design for a small d.c. (direct current electric)-motor-driven robot dubbed the MIT arm. Other members of the computer science and artificial intelligence communities also focused on creating software programs to direct robotic machines in performing dextrous tasks. Their aim was to create devices as humanlike as possible, often with the intent of trying to understand how the human mind and body work.

In 1976 the management of General Motors, aware of the need to further automate its assembly lines, initiated a search for a programmable machine to perform light assembly tasks. This search preceded what has become known as the ‘robot revolution’. At that time very few companies in the United
States had both the interest and the resources to develop such a machine. So General Motors negotiated an agreement under which Scheinman agreed to enlarge his MIT arm and produce two new prototypes. These were called 'programmable universal machines for assembly', or PUMAS.2

Designed with the human arm in mind, the PUMA has six independent controllable motions, commonly called degrees of freedom. A blender, for instance, has one degree of freedom; it can spin in only one direction. The PUMA can rotate at its base, its ‘shoulder’ and its ‘elbow’ and in three independent directions at its wrist.

(ii) Limitations

In the late 1970s, American manufacturers suddenly awoke to the fact that their preeminent position in the global marketplace was being threatened by what they perceived as ‘cheap foreign labour’. That perception, as it turned out, was simplistic. Yet it precipitated a quest for short-term solutions that quickly focused on the fledgling technology of robotics. Many manufacturers believed that the United States could simply build an army of robots with humanoid features that would work in factories day and night, undercutting the advantages of cheap labour abroad. These robots, most people thought, would have manipulators that swung like human arms, grippers that grasped objects like human fingers and sensing abilities comparable with human senses. Made in the image of humans, they would soon outperform humans in cost and efficiency.

This strategy has not worked. It was fatally flawed because it assumed that humans are optimally designed to perform manufacturing tasks and therefore deserve to be emulated. This is not true. Humans are designed to throw stones, pick berries and climb trees. The ability to place a bearing on a shaft has played almost no role in the evolutionary process. In fact, one of the biggest limitations manufacturing engineers have faced is the need to design products that could be assembled by humans. After all, humans cannot generate forces nearly as large as those produced by machines. People are also not particularly precise in their movements, nor are they very adept at stopping and starting suddenly. And compared with machines usually found in factories, they are not very fast. Robots modelled after humans share all these inherent weaknesses.

Humans are, however, good at performing certain manufacturing tasks because their intellectual problem-solving skills allow them to overcome their physical limitations and perform assembly-line work with reasonable cost effectiveness. Human workers can correct for mistakes as they go: if the part does not go in exactly the way they want it to the first time, they will push and prod until it does go in.

Machines are not even remotely comparable in their ability to feel what they are doing or adjust for mistakes. Researchers in industrialized countries are working to install sophisticated touch-sensing skills, binocular vision and
even reasoning capabilities in machines. This research will very likely produce useful results for the factory of the future. But to the extent that it is tied to the concept of a humanoid robot, such research has various limitations.

The six degrees of freedom give the PUMA flexibility in movement but at a cost. When all six joints are linked together end to end, or serially, inaccuracies in movement become cumulative. This means that small errors in the angular orientation of the base create large errors in position at the tip. Thus, by the time the gripper, or 'end effector', moves into action, it cannot manipulate precisely by machinery standards. Furthermore, the more distant joints in the PUMA are limited in their load-bearing capability. This is because the motors that drive the joints at the end of the arm must be relatively small so that the motors closer to the base can carry them. As anthropomorphic robots go, the PUMA is well designed; its limitations are inherent in the mechanical configuration of humanlike arms.

Despite these limitations, hundreds of PUMAs and other comparably configured robots have been manufactured and sold. But only a small fraction of them are being used to perform assembly tasks. To understand why, it is useful to look at a simple task for which the PUMA was tested: that of inserting light bulbs in dashboard assemblies. The robot was programmed to pick up the light bulbs one at a time from pallets where they were carefully arranged. It would then swing quickly to a point near the target socket and slowly push and twist the bulb into place. Because the robot was not capable of sensing that the bulb was sliding into the socket, it performed the task 'blind' by following a carefully learned trajectory. The machine operated under the assumption that both the bulb and the socket were positioned exactly where they should be. The robot was forced to move slowly because it could not produce precise motions at high speeds.

An assembly worker, by contrast, performs such a task by grabbing a handful of light bulbs from a bin and inserting them in rapid succession with a simple twist of a finger and thumb. As General Motors and others have realized, a person can perform such tasks much faster than a robot. Even though robots now incorporate technological innovations such as video camera systems and fingertip sensors, these devices have not significantly enhanced the machines' performance in completing assembly tasks. While much research must be done to determine how to use sensors to improve the capabilities of computer-directed machines, it has become clear that humanlike robots will not soon replace humans at manufacturing tasks that require a significant degree of dexterity.

Even if today's robots could assemble parts as rapidly as a human (and one has yet to encounter a humanoid robot with a fingerlike gripper that comes close), it would still not be a cost-effective alternative to 'cheap foreign labour'. A typical robot may cost around $50 000. Because the parts it is to assemble must be very accurately located for the robot to use them, the hardware necessary to create a workspace around the robot costs another $50 000–$100 000. In addition, there are the costs of programming the robot
to perform specific tasks as well as the costs of set-up, operation, maintenance and repair.

(iii) Strength

Once we rid ourselves of the notion that robots should be made in our image, we can begin asking the right kinds of questions about how they should be designed. For instance, what tasks are human beings not particularly good at? What kinds of manufacturing tasks are better performed by machines?

Today robots are commonly used to spray paint auto bodies and other large surfaces. The machines have been cost effective because a low degree of accuracy is acceptable and low speed is desirable. But the biggest advantage is that robots do not need to breathe. One of the major costs of human-operated spray painting systems is that of providing adequate ventilation; large volumes of air must be carefully filtered to keep workers from inhaling toxic chemicals and to prevent contaminants from affecting the coating process. Since robots do not require breathable air, outside air flow can be kept to a minimum, improving the finish quality of the paint. Robots are better at this task not because they are faster or cheaper than humans, but because they can work in a place where humans cannot.

Robots are also often used for spot welding automobiles. To perform this task, the robot does not have to interact in a carefully controlled way with the piece of work. All it needs to do is anchor the spot-welding tool roughly to a part already lightly welded in place on the car and then apply pressure and electric current. Spot welding has traditionally been performed by skilled labourers working under highly undesirable circumstances. The welding tools can each weigh 100 lb or more, and even though counterbalanced they are difficult to handle. Because of the limitations of human strength, people perform this task more slowly than robots. Large, hydraulically powered robots are the solution of choice in this case because they can do what humans cannot: produce and control large forces.

A third major area where robots are used effectively is that of installing chips on printed circuit boards. Again, this application has proved cost effective because of a capability that robots have and people do not: a robot, once properly programmed, will not put a chip in the wrong socket.

Circuit boards generally cannot be tested until all the components—chips, capacitors, inductors—are in place. If the wrong chip has been inserted or a diode put in backward, the board will not function properly and thus will be useless. Locating and fixing such mistakes can be extremely difficult and time-consuming. Robots have the advantage in 'board stuffing' because the boards they produce have a much greater likelihood of working.

It has often been stated that the greatest virtue of robots lies in their flexibility. The implication is that a manufacturer might best utilize a robot by assigning it to perform a variety of tasks. In fact this almost never occurs. The cost of preparing a robot to perform a single task is very high and is usually
not justified unless the robot is to be dedicated to that task. The primary advantage of flexibility brought about by programmability of a robot is that it can be reprogrammed to accommodate small changes in the task to which it has been assigned. A robot taught to spot weld automobile bodies can easily be retaught to spot weld car bodies of different shapes. But it will probably not be taught to inspect door panels.

(iv) Prospect of future development

Once manufacturers decide what sorts of tasks they want robots to perform, the next step is to reconfigure products to be assembled by the simplest robots possible. The simpler the machines, the faster and more accurately they perform. Yet in the United States, more limited computer-controlled robots have often been dismissed as beneath the state of the art because of their inability to perform tasks in humanlike ways. As a result, many manufacturers in the United States (and Western Europe) who have decided to automate extensively are buying large numbers of robots from the Japanese.

The Japanese have developed families of simple robots with limited degrees of freedom for use in their own factories. While robots in the United States are usually built with six degrees of freedom, the Japanese have deliberately designed robots with fewer joints so they move faster and vibrate less. One of the most popular is the SCARA arm, which has three and in some cases four degrees of freedom. At the same time, the Japanese have designed many of their products to be assembled by the SCARA-type arms and other simple machines. They have also simplified the assembly process to utilize such machines more effectively. For instance, Japanese videocassette recorders are assembled by rows of simple robotic machines, each designed to fit into a preplanned process of production. Furthermore, the mechanical components inside a Japanese videocassette recorder can all be assembled from a single (usually vertical) direction. Not only is this 'Z stack' assembly more efficient, but gravity acts to stabilize the parts during the insertion process. Many North American products, in contrast, are designed so that the components must be inserted sideways as well as vertically, making the transition to simpler robots far more difficult.

The mechanical ability of the simple Japanese machines is limited. But they have one big advantage: they can easily be reprogrammed to manufacture a slightly different model of what they are assembling. Following the Japanese lead, the factory of the future will be based on simple, computer-controlled machines. And such machines will be smaller, faster, more precise and less expensive than existing robots. For instance, today's robots have been designed to reach for parts and then assemble them, much as people do. To reach a large number of parts, robots must have long arms, and the longer the arms, the less precise the motion. In the future, assembly robots will not need such long arms because they will not be expected to reach for parts; inexpensive conveying mechanisms and other devices will deliver parts to them. The
assembly robots will then be free to spend all their time actually assembling products.

In building the next generation of robots, engineers will design end effectors not as grippers but as tools. A robot that uses a gripper to hold a tool is needlessly complex. Humans are limited to operating in this way but machines are not. Machines to which tools can be directly attached can position them much more accurately than machines that hold the tools by a gripping mechanism.

The workspace around the robot will also change significantly. The concept of robots as mechanical humans has prompted engineers to design robots to recognize when a person enters their workspace and to react accordingly. The implication has been that humans and robots are co-workers. As a result, robots have been built to operate slowly and move as humans do to minimize the danger of a mishap.

If robots were treated as the machines they are, this approach could be abandoned, yielding significant savings in production costs. We cannot afford to build robots that operate so slowly that they can accommodate the presence of people in their workspace. After all, few people perceive an arbor press or packaging machine as a co-worker and no one would expect a computer-controlled lathe to stop cutting just because someone touched the spindle. People have no business touching the spindle. Similarly, there is no reason for people to be within the bounds of a robot workspace. Once we recognize that robots are machines, we will begin to build them like machines: fast, reliable and simple to operate.

Most of the work on robot sensors has centred on vision and touch, probably because designers have perceived these as the two most important senses for humans performing assembly work. But robots are not destined to perform assembly in ways that humans do. To be most effective, robot technology will increasingly employ information available from acoustic sensors, pressure sensors, thermal sensors, magnetic sensors and acceleration sensors, as well as from vision and touch sensors. In some assembly lines, for instance, parts could be correctly fitted using acoustic sensors; if the parts are not joined accurately, the sound patterns they emit will be disrupted.

As robots become more reliable, factory performance will become more predictable. Such predictability promises significant cost savings. While assembly costs account for 5–10 per cent of the price of making a typical product, the cost of maintaining an inventory of parts for this product may be as high as 20 per cent. Such an inventory has traditionally provided a buffer against uncertainty. But with predictability comes the ability to determine in advance how many parts of each type will be needed during any given period. With this knowledge, manufacturers can minimize their inventories, requiring instead that suppliers deliver only the number of parts that will be needed ('Just-in-time system').

As automation takes the guesswork out of manufacturing, computers can more easily perform tasks previously assigned to people. These tasks include
ordering the required number of parts and tracking the flow of parts and finished products. The more knowledge one has, the less judgement one needs, and in time computerized expert systems may even be able to make many of the decisions now being made by corporate vice-presidents. Thus, the biggest contribution of robots in the factory of the future will be to create an order that permits computers to replace white-collar workers.4

Much attention has focused on the robot in the evolution of automated manufacturing. However, its role has been and will continue to be relatively small. The key player in the 'automation revolution' is the computer. The use of the computer in factory automation is an area rich with potential for growth and development. But exploiting these possibilities will take time.

2 NUMERICALLY CONTROLLED MACHINES

(i) History

While robots as we know them will not be the vehicles through which the computer will significantly influence the field of manufacturing, there is good reason to believe that computers will have a tremendous impact through enhancing the performance of numerically controlled (NC) machines. The cost of cutting metal in the United States is estimated to be well over $100 billion per year. Throughout recent history, there has been a continuing evolution of technologies for cutting or in other ways forming metal. Conventional lathes and milling machines, used in large numbers through the 1940s, were considered then to be at the state of the art. Today such manually operated machines still make up the vast majority of metal-cutting equipment. But during the last 20 years there has been a significant technological change in that many machine tools are now controlled either directly or indirectly by computers.

During the late 1940s and early 1950s, computers were being created to perform a myriad of computational functions. Within the manufacturing community there was considerable interest in the goal of harnessing the power of the computer to enhance the performance of production equipment. Particularly, it was hoped that computers could control the movements of cutting machines directly and predictably in ways that would minimize errors and maximize throughput. To achieve these goals, several steps were necessary. Motions these machines were to make had to be quantified as series of well-defined actions so that a computer could initiate them in proper sequence. Also, devices had to be developed to measure machinery performance and to convert this information into a format which could be interpreted by a computer. For example, the position of a cutting tool had to be monitored so that the cutting action could be stopped at the correct time.

A great deal of effort was expended in the early 1950s on developing such monitoring devices. This effort resulted in the production of tachometers for measuring spindle turning speeds and shaft encoders and linear scales for measuring tool and workpiece position.
Programmes for directing the actions of the first NC machines were written on remote computers and stored on paper tapes. These tapes, containing coded instructions for directing the machines’ actions, were read and interpreted by a controller on each NC machine. Each controller in turn initiated a sequence of cutting activities while monitoring the machine’s performance to see that the tasks were being carried out. With this technology in place, machined parts in large production runs could be made to be virtually identical with almost no operator intervention. For small lots, the technology was not as useful; it took longer to generate the programme than it would have simply to make the part.

Paper tape was easily damaged and difficult to handle and store. It was soon replaced as the medium of choice by magnetic tape, upon which programmes could be recorded much more compactly. But with magnetic tape as with paper tape, the computer was isolated from the actual cutting operation and could not intervene to modify a cutting sequence while the sequence was being performed.

This situation changed in the 1960s when communication lines began to be run directly from the computer on which the programme was written to the controller on the cutting machine. This change in operating procedure led to the development of DNC or direct numerical control, in which the computer issues commands directly to the machine tool as required in the cutting sequence. The principal advantage to this method is that increased computational power can be brought to bear on the task of machining a part. If a particular batch of metal proved unusually hard, for example, the computer could modify the values for cutting speed to produce an adequate part finish with less tool wear.

An important change occurred in the mid 1970s as a result of the development of microprocessor technology. Microprocessors were installed as components in the controllers attached to NC machines, thus providing the capability for sophisticated process control and even programme editing at the machine on the shopfloor. This system structure, called CNC or computer numerical control, was particularly important in that it reduced system dependence on large central computational facilities and as a result made NC systems available at reasonable costs to smaller, less technologically oriented companies.

(ii) How a system works

Within a computer, very complex strategies are utilized for manipulating information. Unfortunately, the strategies employed for external communication tend to be complex as well. And because these ‘communication protocols’ vary significantly from machine to machine, it is unlikely that any two such devices will be able to exchange information directly. Some translation from one machine’s language to the other’s is almost always necessary. As computer systems have evolved, the task of translation has generally been
assigned to external processors. These processors themselves contain small computers whose job is simply to interpret a message from one source and restructure it into a format which will be understood by another. Commonly called preprocessors if they process information before it arrives at a computer and postprocessors if they act on information produced by a computer, such processors can do more than simply translate. For example, when a computer sends instructions to a machine tool, the intermediate processor might, before transmitting the instructions, check to see that the machine tool is turned on but not already performing a task.

Because various computers are employed to prepare programmes for NC machines and because manufacturers of these machines have adopted a variety of communication protocols, postprocessors play a central role in NC systems. Typically a programmer will write a programme on a central computing facility or on a minicomputer dedicated for that purpose. The programme will probably be written in one of several commonly employed languages. The programmer will then choose and send his programme to a postprocessor which is capable of transforming the programme into computer code which will be understood by the NC machine to be used. For many of today's systems this postprocessor is itself a computer programme which can be run on the same computer that was used in generating the original programme. Large NC facilities which have a variety of NC machines may maintain postprocessors for translating a given programme to be used by any appropriate machine. More commonly, a facility will have only a limited number of machines and will maintain only a few necessary postprocessors.

The postprocessed programme is sent to the NC machine for testing. During this 'shakedown phase' the programmer will carefully monitor the machine's actions, ready to shut it down if a command mistakenly included in the programme causes the machine to move in a way which could damage the machine or the workpiece. Often, feed rates will be reduced for the first run to allow the programmer more time to react. While some sophisticated postprocessors will check the programmes and inform the programmer if he has specified an unsafe or unrealizable motion, many will simply command the machine to do as the programmer has ordered. If the programme performs correctly, the programmer can be assured that, barring some mechanical failure, it will perform identically each time it is used. After a programme has been tested, the programmer may wish to go back to the computer and modify the programme to reduce total cutting time or to change some performance characteristic which he observed during the trial run.

The greatest challenge for people being introduced to NC equipment is overcoming the fear of learning to programme. With each new generation of controller, the task is becoming easier. Unfortunately, documentation is still generally inadequate and computers provide little help in explaining why they will not 'accept' certain commands. Until market forces drive computers to be easier to communicate with, programming will continue to be a rather frustrating activity, particularly for the beginner.
(iii) The current situation

The best machine tool operator in a given shop is more likely to have had 20 years of experience than a college education. Machine tool operation is a craft; it is generally learned from a qualified practitioner and it takes a long time to master. Because the operation of machine tools is a discipline which is learned more through observation than through formal study, it is not susceptible to sudden changes. Numerical controllers provide the potential for such change in the machine tool industry. But in the light of the potential benefits, this change is occurring very slowly.

Not only does the training structure support the status quo, but market forces as well have at times worked against the introduction and growth of the technology. The principal advantage of NC systems is increased system throughput. When the economy slows and machine shops are not at capacity, there is limited incentive to invest in NC equipment. Even a potential economic slowdown somewhere on the horizon has traditionally been enough to discourage the purchase of advanced NC machines, especially by smaller shops.

On the other hand, the number of purchases of NC equipment is increasing because such equipment does have significant advantages over traditional machines. Clearly, machine tools only add value to workpieces when they are cutting metal. And a typical conventional machine tool removes metal during only about 5 per cent of the time available. For best results, both time spent in cutting and rate of metal removal should be maximized. NC machines, because they have been designed and programmed with high performance in mind, meet these goals much more effectively than do traditional machine tools. In addition, because their performance is predictable, they make shop scheduling easier, improve the likelihood that production schedules will be met and reduce waste of material.

NC machine tools are capable of performing cutting operations necessary to produce parts with intricately curved surfaces to very close tolerances. As such, the availability of NC machines extends the designer's ability to create complex components. NC machines are also capable of making production runs of a specific part more repeatably because they are not susceptible to human errors caused by such factors as misinterpretation of specifications, fatigue or lack of skill. As a result, higher overall quality can be achieved for large production runs through use of NC machines.

Another factor influencing the volume of sales of NC machines is the declining cost of computer-based controllers. In general, the companies that make machine tools do not make the controllers for them. The development costs of a controller are very high and the technology required is different from that needed to build machine tools. Controllers are usually manufactured by companies that also make controllers for other products involving motion control. A given controller can be configured to drive machine tools built by a number of companies and so the development costs can be amortised over a large number of sales.
Some of the companies that make controllers for new NC equipment also sell controllers that can be installed on existing traditional machines. While refitting an existing machine is a less expensive alternative, performance of these modified machines is lower than that of a machine designed to be numerically controlled.

Unlike most capital equipment, computers used in NC controllers do not wear out. Yet the expected life for a CNC controller is typically only 3–5 years. As is the case throughout the computer industry, the technology is developing so rapidly that five-year-old equipment, though it continues to perform to specification, has such low performance characteristics when compared with the state of the art that users find it cost effective to trade this equipment in for newer versions.

While it is generally acknowledged that NC machine tools will play a very important role in the factory of the future, in 1983 fewer than 5 per cent of machine tools in use in the United States were numerically controlled. And fewer than 1 per cent of machine tools were operating as part of flexible manufacturing systems (clusters of co-ordinated machine tools and transfer mechanisms).

Traditionally there have been two primary types of machined part production. Piece part (few of a kind) production supplies parts for special-purpose devices and is generally expensive because all set-up time has to be charged to a small number of parts. Mass production is cost effective because it involves part volumes so high that the fraction of the cost charged to set-up time is very small. In an attempt to expand markets, manufacturers are moving towards shorter production runs of larger varieties of products. Availability of NC equipment serves to facilitate this change. Software for creating a component of one product can in many cases be modified slightly to produce the corresponding component of another product. And as production switches from one product to another, no retraining is required and no poor-quality parts are produced during changeover.

While most of this type of work will be handled by conventional NC machines, market forces are pushing for more multifunctional machine tools. Because more flexible machines can perform wider varieties of operations, parts to be manufactured need to be set up on fewer machines. This saves considerable set-up time and also expense in developing jigs and fixtures.

As machine tools become more flexible with greater freedom of motion, they will tend, because of the number and configuration of axes of motion and drive systems, to become less rigid. As with all mechanical systems, versatility comes at a cost in dynamic performance. For best productivity, machines must be run with the highest possible depth of cut and cutting speed. Cutting machines must be very stiff to prevent deterioration of part quality as ‘feed and speed’ increase. So while more flexible machines serve to minimize set-up time, they may fall short in terms of throughput. A good rule of thumb is that a job should be performed on the simplest of the machines capable of completing it.

Greater flexibility will be achieved as NC machines are combined into
flexible manufacturing systems (FMSs). Flexibility is achieved in an FMS through co-ordinated use of machines of diverse capabilities to produce any of a large variety of types of product. For an FMS to be cost effective, tasks must be scheduled to minimize the time that machines are idle. Machine tools chosen for inclusion in an FMS should be selected to create a balance of system capability which will maximize throughput.

Lack of standards is a serious impediment to the development of flexible manufacturing cells. Without standards, communication among the control computers on machines in an FMS is difficult to coordinate. Also, lack of standards for mechanical tooling interfaces prevents various machines from exchanging end tooling. While some standards have been set, many machine tool manufacturers have chosen not to acknowledge them.

Interface standardization facilitates upgrading of existing equipment. It also makes possible gradual expansion of capability in an FMS. Without universal standards, larger machine tool manufacturers, because they have larger product lines, will be in a better position to provide complete manufacturing cells. Smaller manufacturers may then be forced to sell their equipment primarily to the larger manufacturers, who will adapt it to fit in their systems.

(iv) Machine tools in the future

Various technologies will play a role in the future of NC machines. New materials will lead to longer life for cutting tools. Better analytical methods will facilitate design of faster, stiffer machines. But the major driving force for change in the industry will continue to be development of computer technology.

Computers are now used primarily to control the motions of NC machines in response to programmes written for each part to be made. Soon computers will be used to process information about system performance. The goal of this processing will be to help the machines to operate more predictably and as a result to make the factory easier to manage.

Computers will be used to record the duty cycles of each machine and to maintain information for use in more effectively predicting 'downtime' and scheduling routine maintenance. Computers will collect data from sensors mounted on the machine tools for the purpose of perceiving faults and predicting system failures so that potential problems can be averted. Sensors for determining the onset of chatter will communicate with a computer which will in turn regulate feeds and cutting speeds accordingly. Computers will monitor condition of the tool and when necessary will initiate a process of precisely positioning a replacement. All these monitoring functions will serve to minimize the effects of unexpected occurrences. This will in turn improve predictability, which will lead to more reliable estimates of delivery time and more effective utilization of capital equipment.

As manufacturers move to minimize production of bad products, quality of components is becoming more important. Computers will be used to calibrate
the motions of each NC machine in a system and to modify the tool path to correct for any machine inaccuracies.

As mentioned previously, NC programmes are now generally checked by using them to make a 'trial part'. This method ties up the machine tool and, if the programme is poorly written, may cause damage. In time, computers will be used to check programmes for mistakes and eventually to propose corrections. Computers will also be able to study a mechanical drawing and to determine the best path for the cutting tool to follow in making the part. Technology for these advanced computer applications will be expensive to develop. As a result, most of the development work will be done within the larger companies, who will subsequently benefit from the accompanying competitive edge.

Parts are regularly made on machine tools and then measured to see if they meet the specifications. As a result, time is lost making parts which do not meet specification. In the future, precise measurements of the part will be made as the part is being machined. This 'in-process gauging' will guarantee that all parts are manufactured to specification. As an NC machine operates, its motors create heat, causing it to expand and deform slightly near the motors. For very high precision cutting applications, computers will monitor temperature at various points on the machine and will control directed air or coolant flow which will maintain constant temperatures and prevent thermal distortions.

The demand for greater accuracies will increase with time. For example, the automobile industry is manufacturing larger more complex parts to replace assemblies of parts. Fewer parts means fewer sources of adjustment. To fit, these larger more complex parts will have to be made more accurately.

The effects of computers on performance of machine tools will not all occur at the factory floor. At a future time, machine designers will perform all their work in cooperation with CAD/CAM systems, which are basically computer systems programmed to facilitate the design, display, manufacture and debugging of mechanical components. These CAD/CAM systems will incorporate computer programmes which will evaluate the designs, suggest modifications for improving performance or reducing cost, and then will select the machine tools on which the parts will be manufactured, plan the cutting sequences and generate commands for directing the machine tools.

3 THE ROLE OF THE WORKER

Changes noted in the previous sections will have a significant impact on the working environment. However, impact to date has been minimized by the fact that introduction of the technology has been slower than had earlier been expected.

Several countries, including the Federal Republic of German, Norway and Sweden, have laws which require that workers have the opportunity to influence the introduction of new technologies. These laws attempt to regu-
late allowable rates of change. Some labour contracts, among them the agreement between Nissan Motors and its employees, provide labour with the opportunity to regulate rates of introduction of new technology and guarantee job security for those who might otherwise be displaced.

It is generally argued that a shortage of qualified operators has developed in the machine tool industry and that NC machines are serving to help manufacturers to cope with the shortage. It is true that between 1938 and 1945 a large number of people were trained to operate machine tools and that these people are now retiring from the labour force. However, the introduction of NC machines has broad implications for the operators who remain on the job.

One issue is that of deskill ing. It takes less skill to monitor and handle parts for an NC machine than it does to operate a standard machine. Thus, training periods for NC operators may be shorter. And shorter training periods lead to expansion of the pool of available workers and correspondingly to a reduction in wage levels. Because operation of an NC machine is generally less challenging, operators trained on standard machines find working on NC equipment to be boring, particularly when the work involves long running times or large lot sizes. (It has been noted that people whose training was on NC machines are less likely to experience this boredom.)

For those whose jobs are lost because of introduction of NC machines, there are questions as to the extent to which employers should finance retraining programmes. For many workers no longer able to find jobs operating machine tools, employers may be expected to provide job counselling and career guidance. These workers are well-qualified candidates for retraining as NC machine programmers. Their experience and expertise will be very helpful to them in creating efficient programmes. However, as mentioned earlier, developing competence in the use of a programming language may require considerable time and effort.

Because NC machines operate in coordination with control computers, monitoring of their performance is straightforward. And there is a subtle distinction between monitoring of machine performance and monitoring of operator performance. Along the same lines, with NC machines, the pace of the operations to be performed can be regulated, forcing the operator to maintain an inordinately high level of activity.

There are several paths which an enlightened manager might follow when changing to NC equipment. All machinists affected by the change should be encouraged and trained to programme the new machines. In this way their talents would be most fully utilized. The machinists who do learn the programming language should be allowed to edit programmes being sent to the machines they operate. Because they are monitoring the job, they are the most able to discover and implement constructive changes. Machinists who have been trained as programmers should regularly be given the opportunity to 'rotate through' the programming department. In this way their programming skills will remain sharp. These workers should also periodically take
shifts on conventional machines; the change will provide variety and possibly more challenge.

Use of NC machines has the potential to make jobs more interesting. In a thoughtfully planned environment, workers could be freed of some of the more mundane tasks and given the opportunity to correct or improve programmes, conduct quality control tests and monitor plant operation. In a more diverse shop with sophisticated equipment, maintenance positions would be more challenging and require greater technical skills. Where possible, the more boring tasks would be done by machines.

More important, workers should be made to feel that they have control of their activities. Job stress and general dissatisfaction result when people feel overworked and deprived of decision-making authority. Machine performance data collected by computers should not be used as a basis for threatening workers with disciplinary action; such threats are likely to leave machine operators feeling manipulated by and resentful of the technology with which they work.

Some Japanese companies employ a strategy for introducing new technology which they call ‘slow-fast’. A great deal of time is spent in preparation for change. People are consulted about methods of implementing change, informed of the effects of the proposed change both favourable and unfavourable and given the opportunity to express their preferences. Before a change can be implemented, consensus must be reached over the means of doing so. This process is slow and takes a great deal of energy. However, it will facilitate the rapid (fast) implementation of change once consensus has been reached. While the total time required to make changes in this manner may be equal to or greater than that required with other schemes, worker frustration and resistances will be reduced substantially.

4 CONCLUSIONS

It is important for us to think about the best ways to introduce new NC machine technology because in the coming years there will be a great deal of such technology to introduce. Computers will be used much more to organize the flow of parts through manufacturing facilities. Expert system programmes will become sources of knowledge about best practices in machine tool operation. Computers will plan tool paths, choose feeds and speeds, monitor quality and keep track of the maintenance needs of the machine tools and possibly the personal needs of the operators. Computers will train new workers in machine tool technology and retrain them when necessary. Computers will order the raw materials, control inventories, estimate delivery dates and bill customers.

The computer offers the potential for significant improvement in the quality of the working environment. There is also the potential for this quality to be degraded. Decisions on how the technology is used will be made not by
computers but by people. Machine tool operators must begin to prepare themselves to play an active role in the decision-making process which will direct these changes.

NOTES
1 The section on robotics is an adaptation of the author's article which appeared in the April 1985 issue of Technology Review.
2 When General Motors first initiated this experiment, there was little interest in producing robots for assembly in the United States. But the press coverage accompanying the delivery of the PUMAs provoked a groundswell of enthusiasm and by 1981 more than 150 robot companies had sprung up in the United States. The standard joke at robotics trade shows that year was that more companies were manufacturing robots than buying them. If one discounts the robots sold to research laboratories, that was probably true.
   There were several reasons for this sudden flurry of activity. To alarmed manufacturing executives, the idea of purchasing robots to replace expensive and uncooperative workers seemed much more appealing that the thought of making fundamental renovations in their antiquated production systems. Furthermore, there were few barriers to entry into the robot market. The mechanical technology in robots was fairly traditional and well understood and any good mechanical designer could build one with the help of a computer wizard. In 1980, venture capitalists were eager to fund such operations.
3 Editor's note: It is in this sense that 'flexibility' of microelectronic equipment is discussed in the automobile industry, as will be made clear in subsequent chapters.
4 Roger Smith, chairman of the board of General Motors, recently announced the establishment of Saturn Corporation, the first new automobile manufacturer to become part of General Motors since Pontiac in 1926. Smith claimed that the new company will thoroughly computerize its manufacturing and sales operations. The plan, he said, is to 'run the corporation without paperwork'. He added, 'Maybe we won't even need a mail boy.'
5 Expert system programmes are computer programmes which store and manipulate information gathered from experts in a given field. While few expert system programmes are in use today, they are becoming more common. Typically such a programme is prepared by a person qualified in the area of interest who interviews a variety of experts and selects from the interviews facts and opinions about performance of a series of tasks. This information is stored in a data base and subsequently manipulated by the computer programme to provide answers based on the collective wisdom of the experts to questions posed by interested practitioners or possibly by decision-making computers.

REFERENCES
CHAPTER III

Flexible Automation and Labour Productivity in the Japanese Automobile Industry

Susumu Watanabe

This chapter first examines the trend of labour productivity (vehicle production per worker or work hour) and the time pattern of the diffusion of NC machine tools and robots in the Japanese automobile industry (Sections 1 and 2). It will be shown that, by the time the diffusion of these machines began to accelerate around 1980, the phase of a rapid productivity increase in this industry had passed. On the basis of a survey of about 60 firms, Section 3 explores the reasons why the labour-saving effect of the microelectronic technology has been so limited. In doing so, the motivation and mode of application of the new machinery, as well as constraints on it, will be discussed with respect to three groups of firms, assemblers, major component manufacturers and small subcontractors. It will be made clear that there are some important differences among these firm groups in the use of the new technology and its impact.

1 TRENDS OF THE INDUSTRY

(i) Production and employment

The Japanese automobile industry grew in two phases (Table 1). The first period of rapid growth was the decade starting in the late 1950s, when motorization advanced rapidly as a result of economic growth of nearly 10 per cent per annum. The next period of expansion was the second half of the 1970s, when demand for fuel-efficient Japanese cars grew rapidly in export markets, especially in the United States. Exports rose from just over one million units in 1970 to 2.6 million by 1975 and 6 million by 1981.

Employment in the industry, however, increased much more slowly than output: between 1965 and 1982 automobile production increased sixfold while employment increased by 67 per cent only. Both production and employment declined twice, first in the wake of the oil crisis of 1973–74 and
### Table 1: Production and employment in the Japanese automobile industry (in '000 vehicles and workers except (5))

<table>
<thead>
<tr>
<th>Year</th>
<th>Production units</th>
<th>Employment</th>
<th>Output per worker (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
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<td>(2)</td>
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<tr>
<td></td>
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</tr>
<tr>
<td>1960</td>
<td>481.6</td>
<td>74.4</td>
<td>201.1</td>
</tr>
<tr>
<td>1965</td>
<td>1875.6</td>
<td>116.0</td>
<td>300.4</td>
</tr>
<tr>
<td>1970</td>
<td>5289.2</td>
<td>154.6</td>
<td>425.4</td>
</tr>
<tr>
<td>1971</td>
<td>5810.8</td>
<td>178.8</td>
<td>396.1</td>
</tr>
<tr>
<td>1972</td>
<td>6294.4</td>
<td>174.7</td>
<td>432.5</td>
</tr>
<tr>
<td>1973</td>
<td>7082.8</td>
<td>184.8</td>
<td>449.6</td>
</tr>
<tr>
<td>1974</td>
<td>6551.8</td>
<td>182.9</td>
<td>431.8</td>
</tr>
<tr>
<td>1975</td>
<td>6941.6</td>
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<tr>
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<td>7841.4</td>
<td>172.0</td>
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<td>1977</td>
<td>8514.5</td>
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<tr>
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<td>9269.2</td>
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<td></td>
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<td>187.0</td>
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<td></td>
<td>(11736.1)</td>
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<tr>
<td>1982</td>
<td>10731.8</td>
<td>191.8</td>
<td>504.5</td>
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<tr>
<td></td>
<td>(11353.8)</td>
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<td>1983</td>
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</tr>
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<td></td>
<td>(11899.5)</td>
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<td>11464.9</td>
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<td>530.0</td>
</tr>
<tr>
<td></td>
<td>(12388.0)</td>
<td></td>
<td>(17.2)</td>
</tr>
</tbody>
</table>

**Notes**

1. Production figures are related to four-wheelers only. Until 1978 they include KD (knocked-down) sets. After 1979 comparable figures are given in parentheses.
2. Employment figures include workers engaged in the production of three-wheelers (until 1974) and motorcycles.

From JAMA: *Jidōsha Sangyō Kanren Tōkei* and *Nihon no Jidōsha*, various issues.

Second in 1982 due to the recession of the world economy which led to import restrictions by industrialized countries. The delayed recovery of employment in the mid-1970s was a reflection of the widespread and continued rationalization effort by the industry. The single most important contributing factor was Mazda's crisis, which resulted from the serious blow to the market for rotary engine vehicles brought about by the increase in oil prices. The company did not resume recruitment of new school leavers until 1979.

The second half of the 1960s was a crucial period for the development of the industry. As shown in Table 2, car production per hour worked increased
Table 2: Growth of hourly output in the Japanese automobile industry (1965–83)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Total hours worked per car</th>
<th>Unit of car produced per work hour</th>
<th>Ratio of hourly output as compared with 5 years before</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>98.39</td>
<td>0.0010</td>
<td>—</td>
</tr>
<tr>
<td>1970</td>
<td>54.60</td>
<td>0.0183</td>
<td>18.3</td>
</tr>
<tr>
<td>1975</td>
<td>38.72</td>
<td>0.0258</td>
<td>1.40</td>
</tr>
<tr>
<td>1980</td>
<td>26.42</td>
<td>0.0378</td>
<td>1.46</td>
</tr>
<tr>
<td>1983</td>
<td>29.38</td>
<td>0.0340</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*The publication of the series of official statistics underlying this table and cited in the Annex was discontinued in 1984.

*b*Total hours worked per car' includes both production and supporting activities and both assembly and component manufacturing.

See Annex for source.

eighteen-fold during this period. By the early 1970s, output per worker in Japan surpassed the levels of other industrialized countries (less than ten vehicles per worker except in the United States). However, it only doubled over the next ten years, and somewhat declined after 1980.

Automobile assemblers attribute this reversal of the trend of output per worker (or the number of hours worked per vehicle) primarily to the levelling off of car production (the increase in the *per capita* output including KD (knocked-down) production in the last two years supports this view), but also to an increasing variety of vehicles and the rising numbers of accessories which give rise to more work per vehicle. In the supporting activities, a more thorough implementation of the 'just-in-time system' calls for a greater amount of transport services. Maintenance and repair work increase as a result of both diffusion of more sophisticated production equipment such as NC machine tools and robots and multiplication of production lines, machines and tools which are required to produce greater varieties of vehicles and their components. Testing involves more work as the vehicle becomes more heavily loaded with functional equipment. Last, but not least, a shortened product cycle, greater degrees of differentiation of vehicles and components, increased numbers of functional components and higher degrees of product sophistication all imply growth of R&D work, including designing and prototype production. In brief, the amount of work required per unit of vehicle has increased considerably.²

In the meantime, the rapid and extensive technological changes brought about important shifts in the occupational composition of the workforce in the industry. The proportion of production workers fell almost steadily from 57 per cent to 45 per cent between the early 1960s and the early 1980s, while that of administrative and technical staff rose from 19 per cent to 34 per cent. The proportion of maintenance workers remained relatively stable.³ The
rising importance of administrative and technical staff seems to be partly attributable to the increasing R&D effort in this industry. According to a survey which the Japan Auto-Parts Industries Association (JAPIA) conducted in June 1982 with 112 member companies' cooperation, R&D staff increased by 38.2 per cent between 1977 and 1981, while total employment at these firms rose by 10.8 per cent only.\(^4\)

(ii) Contributors to labour productivity improvement

The rapid increase in hourly output per worker was a combined effect of different factors: the economies of larger-scale production of individual models, the automation of production processes, the rationalization of work organization and the improvement of product design and specification, including applications of new materials. Until the oil crisis of 1973–74 the first two were the main contributors, while in the subsequent period the latter two became almost the sole explanations. For our later analysis it is necessary to elaborate on this point.

As in most other industries of the country, modernization of the automobile industry started after the drastic rationalization programme (‘Dodge Line’) of 1949, which caused closure of obsolete plants and massive dismissal of workers. In those days, the Ministry of International Trade and Industry (MITI) believed that technologically this industry was 20–30 years behind its western counterparts.\(^5\) To catch up as quickly as possible, vigorous efforts got under way. Modern management techniques and scientific quality control techniques (QC) were imported from the United States: industrial engineering techniques (IE) in 1955 and system engineering, value analysis, etc., by around 1960. IE techniques like time, movement and flow studies helped reduce the production cost considerably through replacement of the ‘batch production method’ with the ‘flow production method’ as well as through standardization of work. The special procurement boom of the Korean War (1950–52) helped capital accumulation and encouraged replacement of obsolete machinery in subsequent years: ‘... from 1955 to 1959, desperate efforts were made to catch up with, and surpass, rivals in the United States and Western Europe by means of productivity increase in every production process through application of automatic and high-speed equipment and through rationalization efforts aimed at elimination of wastes. As a result, preparation for the introduction of mass-production system was completed.’\(^6\)

A ‘block-built’ special-purpose machine replaced three or four general-purpose machines. By redesigning and by attaching an air-chuck, a hydro-chuck, a limit switch, etc., existing machines were automated. Maintenance of tools was centralized and a system was introduced whereby new tools were delivered to the operator regularly to replace the previous tools after a certain amount of work. Introduction of automatic material-handling devices (e.g. loaders and unloaders) reduced manual work. Far greater was the effect of the ‘stoppers’ attached to automatic machines in order to interrupt their
operation whenever something began to go wrong. With the origin of its basic concept in Sakichi Toyota’s automatic weaving loom, this device (of various kinds) gave rise to a new concept of work in the machining shop. Machining was done by the machine and not by the operator. The operator’s service was required only when and where the machines stopped. Consequently Toyota’s employees were tending up to seventeen machines by October 1957.

The increase in the machine–worker ratio had significant implications for training. Where the machines were organized in a flow production system, the set of machines attended by an operator often consisted of different types of machines, such as lathes, milling machines and drilling machines. Workers were therefore encouraged to master a variety of machines through on-the-job training in the course of their service with a firm (‘Tanōkō-ka’).

Toyota and Nissan introduced their first transfer machines in 1956 and Mazda followed suit the following year. Application of computers in office work had begun a few years earlier. In March 1959, the Government decided to liberalize trade as required by its membership of OECD and IMF and urged industries to modernize and increase their scale of production to internationally competitive levels, if necessary by merger. Prime Minister Ikeda’s ‘Income Doubling Plan’ was announced and a plan for the industry was formulated in 1960. Individual companies drew up their expansion programmes. Influential in this process was Maxcy and Silberston’s study (1959), which demonstrated the critical importance of the scale of production in determining productivity in the automobile industry. Consequently, the industry’s capital investment in 1962 was sixteen times as much as in 1955. Until 1970, the level of annual fixed capital investment remained over 30 per cent of the industry’s gross profit (value added minus wages and salaries) (Table 3). The high rate of investment was primarily aimed at labour saving by means of large-scale ‘fixed’ automation technology, such as transfer machines. This was necessary because the Japanese economy passed its ‘turning point’ from the labour surplus to the full employment phase around 1960, and because institutional barriers forbade the Japanese to adopt the European and North American solution to the labour shortage, i.e. importation of cheap labour from abroad.

Between the late 1950s and the early 1960s, major plants designed for mass production of passenger cars appeared: Toyota’s Motomachi No. 1 and No. 2 plants, Nissan’s Oppama plant, Isuzu’s Fujisawa plant, Prince’s Murayama (now Nissan) and Hino’s Hamura plant. (Eventually, Isuzu, Prince and Hino lost the competition and joined either Toyota’s or Nissan’s group.) Gradually, former producers of trucks, three-wheelers and motorcycles such as Mazda, Mitsubishi, Daihatsu, Fuji and Honda joined the race by constructing mass production plants. Specialized in production of particular models of cars or certain components (e.g. engine blocks), these plants adopted an integrated production system centrally controlled by computers. Various processes were highly automated: machining by means of transfer machines, stamping by transfer presses, welding by multi-spot welders, etc. The testing process was
Table 3: Gross fixed capital investment on the expenditure basis by sector of the automobile industry* (in hundred million yen)

<table>
<thead>
<tr>
<th>Year</th>
<th>Assembly</th>
<th>Body</th>
<th>Parts and components</th>
<th>Total at current prices</th>
<th>Total at constant prices\textsuperscript{b}</th>
<th>Percentage of investment in gross profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY1962</td>
<td>703</td>
<td>27</td>
<td>169</td>
<td>899</td>
<td>n.a.</td>
<td>36.1</td>
</tr>
<tr>
<td>1963</td>
<td>792</td>
<td>36</td>
<td>178</td>
<td>1 005</td>
<td>n.a.</td>
<td>30.3</td>
</tr>
<tr>
<td>1964</td>
<td>1170</td>
<td>96</td>
<td>199</td>
<td>1 465</td>
<td>n.a.</td>
<td>36.5</td>
</tr>
<tr>
<td>1965</td>
<td>1231</td>
<td>80</td>
<td>179</td>
<td>1 490</td>
<td>3 204</td>
<td>36.4</td>
</tr>
<tr>
<td>1966</td>
<td>1185</td>
<td>54</td>
<td>181</td>
<td>1 423</td>
<td>2 989</td>
<td>30.6</td>
</tr>
<tr>
<td>1967</td>
<td>1948</td>
<td>134</td>
<td>420</td>
<td>2 501</td>
<td>5 210</td>
<td>38.6</td>
</tr>
<tr>
<td>1968</td>
<td>2417</td>
<td>162</td>
<td>434</td>
<td>3 013</td>
<td>6 264</td>
<td>35.6</td>
</tr>
<tr>
<td>1969</td>
<td>2457</td>
<td>103</td>
<td>427</td>
<td>2 987</td>
<td>6 034</td>
<td>32.0</td>
</tr>
<tr>
<td>1970</td>
<td>2825</td>
<td>205</td>
<td>626</td>
<td>3 656</td>
<td>7 197</td>
<td>32.1</td>
</tr>
<tr>
<td>1971</td>
<td>2266</td>
<td>165</td>
<td>511</td>
<td>2 942</td>
<td>5 837</td>
<td>28.6</td>
</tr>
<tr>
<td>1972</td>
<td>2498</td>
<td>177</td>
<td>612</td>
<td>3 287</td>
<td>6 285</td>
<td>28.4</td>
</tr>
<tr>
<td>1973</td>
<td>2989</td>
<td>310</td>
<td>974</td>
<td>4 274</td>
<td>6 689</td>
<td>31.2</td>
</tr>
<tr>
<td>1974</td>
<td>3757</td>
<td>216</td>
<td>894</td>
<td>4 867</td>
<td>6 379</td>
<td>37.4</td>
</tr>
<tr>
<td>1975</td>
<td>2606</td>
<td>179</td>
<td>583</td>
<td>3 368</td>
<td>4 335</td>
<td>22.7</td>
</tr>
<tr>
<td>1976</td>
<td>3014</td>
<td>208</td>
<td>696</td>
<td>3 918</td>
<td>4 766</td>
<td>18.7</td>
</tr>
<tr>
<td>1977</td>
<td>4504</td>
<td>287</td>
<td>1077</td>
<td>5 868</td>
<td>7 028</td>
<td>24.1</td>
</tr>
<tr>
<td>1978</td>
<td>4425</td>
<td>366</td>
<td>1169</td>
<td>5 960</td>
<td>7 198</td>
<td>23.3</td>
</tr>
<tr>
<td>1979</td>
<td>4792</td>
<td>450</td>
<td>1188</td>
<td>6 430</td>
<td>7 113</td>
<td>21.6</td>
</tr>
<tr>
<td>1980</td>
<td>7513</td>
<td>552</td>
<td>2205</td>
<td>10 270</td>
<td>10 158</td>
<td>32.8</td>
</tr>
<tr>
<td>1981</td>
<td>8606</td>
<td>669</td>
<td>2443</td>
<td>11 718</td>
<td>11 568</td>
<td>33.7\textsuperscript{c}</td>
</tr>
<tr>
<td>1982</td>
<td>8484</td>
<td>546</td>
<td>1426</td>
<td>10 456</td>
<td>10 301</td>
<td>30.1\textsuperscript{c}</td>
</tr>
<tr>
<td>1983 (est.)</td>
<td>6757</td>
<td>465</td>
<td>1959</td>
<td>9 180</td>
<td>9 125</td>
<td>n.a.</td>
</tr>
<tr>
<td>1984 (plan)</td>
<td>6808</td>
<td>367</td>
<td>1917</td>
<td>9 092</td>
<td>9 020</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

*Includes facilities for the production of two- and three-wheelers. Investment figures are related to fiscal years and gross profit figures to calendar years. Owing to rounding, some of the figures do not add up exactly to the total.

\textsuperscript{b}The investment figures at constant prices were computed using the domestic wholesale price indices for industrial products, which are published in the Bank of Japan: \textit{Annual Economic Statistics (Tokyo)}, various years.

\textsuperscript{c}Overestimated because gross profits of establishments with three or fewer workers are not included in calculation.


also mechanized. The power system in the plants was rationalized by means of the introduction of power zones. Maintenance of equipment was centralized. Treatment of scrap was also rationalized with the help of simple automatic devices.\textsuperscript{13} At Toyota, the die-changing time for the pressing machines fell from two to three hours before 1955 to fifteen minutes by 1962 (and to three minutes by 1971).\textsuperscript{14}

The automobile assemblers' success in these technological and organizational innovations for mass production depended critically on the reliability of their parts and component suppliers with respect to both quality and delivery
of their products. The latter firms' performance was, in turn, determined largely by their subcontractors, who had their own subcontractors. The assemblers' efforts for modernization and rationalization, therefore, became their groups' efforts, as most of the major component manufacturers and many subcontractors in Japan are 'tied' to one particular assembler or parent firm. Competition among the assemblers was competition among the groups. Consequently, technical, financial and managerial guidance and assistance from parent firms at each level of the subcontracting hierarchy grew as the modern mass production system spread in the industry.15

Partly as a result of such support received from the assemblers, the machining process at major component manufacturers' plants was semi- automated in the second half of the 1950s. General-purpose machines were used for single purposes and were converted into semi-automatic machines by means of simple devices. The operators' work was simplified so that young school leavers could be employed for the expansion of output. The machine-man ratio of 4 or 5 became common and transport (transfer) of workpieces was rationalized. After 1960, the firms started building large highly automated plants. From the mid-1960s to the end of the decade, the scale of production of certain items reached 100,000 to one million pieces a month. Consequently, at some of the major component makers' plants, production processes, including welding, painting and assembly, were organized into lines. The stamping process was either partially or entirely automated. Automation of the machining process advanced. Synchronization of work at different processes was pursued.16

The oil crisis and subsequent world depression changed the situation drastically. Apart from the construction of a few plants (Toyota's Tsutsumi and Tahara plants, Nissan's Kyushu plant, Mitsubishi's Okazaki plant, for example) which were designed to meet the expanding export demand, most investment projects were intended for the production of low fuel consumption, low pollution cars. In the meantime, the one-chip microprocessor appeared in 1974, to lower the costs and increase the reliability of NC machine tools and, later, robots. As will be shown in the next section, the automobile industry began to accelerate application of these new machines towards the end of the decade, primarily in pursuit of a greater flexibility of production facilities and of a higher degree of product differentiation and sophistication. The rate of capital investment remained high but its objective changed. This is clearly reflected in the trend of the hourly output per worker, which was discussed above.

Improvement of labour productivity does not always accrue from investment aimed at automation. Simple devices such as loaders, unloaders, chutes and stoppers have been one of the most important contributors to the productivity improvement in Japanese industries. They are often developed and produced by workers to meet the specific needs of their work posts, as part of their 'QC circle' activities. The QC circles spread in different industries from the mid-1960s onwards, when Japanese firms encountered serious
quality control problems in a process of rapid growth of output despite the application of modern quality control techniques imported from the United States. Factory workers were organized into groups ('circles') of 5–20 people. These groups were to review regularly the existing work practices with a view to improving not only the quality of work and product but also productivity and conditions of work, for example by developing and producing simple devices and by changing work organization and plant layout. The QC circle activity usually goes with the 'suggestion scheme (Teian Seido)', whereby adopted ideas are awarded certain prizes.¹⁷

The impact of the QC circle activities may be illustrated with reference to Mazda's experience. In June 1962, this company launched a special automation programme which relied entirely on low-cost devices developed in-house. In 1963, simple automatic devices were attached to eight out of a total of eleven machines on the cylinder production line. Two machines became redundant and the number of workers on the line was reduced from nine to three. Subsequently, a similar change took place on lines producing the camshafts, pistons, rear axles, gears, etc. By the end of 1966, 624 devices were produced, ranging from auto-loaders to automatic assembly and heat treatment equipment. Processing of about 30 kinds of parts and components and transport (transfer) of some 80 parts and components were automated.¹⁸ Mazda's experience is not at all exceptional. For example, Honda has a 'hand-made automation' programme under which even robots are built by workers. People in this industry consider QC circles to be a major contributor to productivity increase, as will be discussed in Section 3. It is possible that their importance has increased over time, as the limit to labour saving through mass production technology has approached.

It is also true that various innovations which are not directly intended for labour saving create significant effects on productivity. An important example is the 'just-in-time (or Kamban) system'. Originating from Toyota,¹⁹ this system spread steadily among other Japanese automobile assemblers' plants, and later among the component makers and gradually among their subcontractors (after 1963 in the case of the Toyota Group). One important aspect of the system is the regularization of the flow of work. If 1000 units of a given type of parts are needed for the month (25 working days), for example, 40 units will be produced a day, and at a constant pace during the day. In this way, it becomes unnecessary to maintain a sufficiently large production capacity (machine tools, workforce, materials, etc.) to meet peak demand. At the same time, the elimination of stocks of parts and components implies a stoppage of the entire production process once a machine breaks down somewhere. Rejection of received parts and components will cause a similar problem. Therefore, meticulous care will be taken in the maintenance of production facilities and the quality control. Both regularization of work flow and decline in downtime enhance productivity.²⁰

Figure 1 summarizes major on-going, and often interrelated, technological changes in the automobile industry, including relatively new phenomena (e.g.
Figure 1  Recent technological changes in the Japanese automobile industry.
flexible automation and new materials)\textsuperscript{21} and developments continued from earlier years (e.g. ‘just-in-time system’ and QC circles). To a smaller or greater degree, each of them influences labour productivity in the industry, as will be touched upon in Section 3.

2 DIFFUSION OF MICROELECTRONIC EQUIPMENT

Since 1976 the automobile industry has been the second largest user of NC machine tools, after the general machinery industry. Diffusion of NC machine tools accelerated towards the end of the 1970s (Table 4): only 564 units were shipped to the automobile industry over the three-year period 1975–77. The most popular NC machine in this industry is the lathe, but the use of machining centres (MCs) and NC special-purpose machines has been increasing rapidly. This industry is also the second largest user of robots, only marginally behind the electrical and electronic machinery industry. By the end of 1984, about 14,000 robots of playback and higher categories had been acquired (Table 5). The diffusion of robots accelerated remarkably after 1980, so much so that the Japanese often refer to that year as ‘the first year of the robot era’. Since some of the newly acquired NC machines and robots have replaced older ones, the actual stock is smaller than the cumulative shipment figures in these tables. (Imports of these machines have been negligible.)

Since 1978, small and medium-sized enterprises (fewer than 300 workers) have accounted for about 60 per cent of the total domestic demand for NC machine tools, in terms of the value. Enterprises with fewer than 30 workers purchase about a quarter of those sold domestically.\textsuperscript{22} It should be remembered, however, that in 1980 there were over 250,000 establishments with fewer than 50 workers and 11,600 establishments with 50–299 workers, against 1,931 establishments with 300 or more workers in the metal engineering industries (Standard Industrial Classification (SIC) groups 33–38). The numbers of enterprises are naturally somewhat smaller than those of establishments, but the fact remains that the microelectronic machines shipped to small and medium-sized enterprises are dispersed very thinly. The diffusion of robots among these enterprises is marginal, accounting for less than 20 per cent of the total expenditure of the automobile industry on manipulators, fixed- and variable-sequence equipment and robots.\textsuperscript{23}

Regional surveys conducted by prefectural governments and other institutes in various parts of the country confirm limited use of NC machine tools and robots in the small sector. For example, the surveys conducted in Nagoya (SIC 33–37, 200 firms) and in Osaka (SIC 34–37, 401 firms) in the second half of 1982 both found that the proportion of users of microelectronic production equipment was below 40 per cent for firms with 10–29 workers as compared with over 70 per cent for firms with 300 or more workers. Neither survey found any robot in the smallest size group (10–29 workers in Nagoya and 1–9 workers in Osaka).\textsuperscript{24}
Table 4: Shipment of NC machine tools to the automobile industry and to the national market by type of machine, 1978–84

<table>
<thead>
<tr>
<th>Machine</th>
<th>Automobile industry</th>
<th>Total 1980–84</th>
<th>National total 1980–84</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lathes</td>
<td>n.a.</td>
<td>n.a.</td>
<td>1049</td>
</tr>
<tr>
<td>Machining centres</td>
<td>n.a.</td>
<td>n.a.</td>
<td>189</td>
</tr>
<tr>
<td>Milling machines</td>
<td>n.a.</td>
<td>n.a.</td>
<td>73</td>
</tr>
<tr>
<td>Special-purpose</td>
<td>n.a.</td>
<td>n.a.</td>
<td>26</td>
</tr>
<tr>
<td>machines</td>
<td>n.a.</td>
<td>n.a.</td>
<td>158</td>
</tr>
<tr>
<td>Other</td>
<td>n.a.</td>
<td>n.a.</td>
<td>1915</td>
</tr>
<tr>
<td>Total</td>
<td>506</td>
<td>782</td>
<td>1495</td>
</tr>
</tbody>
</table>

*Metal-cutting machines only. Japanese NCs are mostly CNCs.

From Nihon Kōsakukikai Kōgyōkai (Japan Machine Tool Builders Association—JMTBA).
Table 5: Shipment of manipulators and robots to the Japanese automobile industry and to the national market, 1978–84

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Automobile industry</th>
<th>Total 1980–84</th>
<th>National total 1980–84</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Manual manipulator</td>
<td>110</td>
<td>153</td>
<td>268</td>
</tr>
<tr>
<td>(2) Fixed sequence</td>
<td>679</td>
<td>1383</td>
<td>1995</td>
</tr>
<tr>
<td>(3) Variable sequence</td>
<td>208</td>
<td>344</td>
<td>126</td>
</tr>
<tr>
<td>(4) Playback robots</td>
<td>277</td>
<td>314</td>
<td>1167</td>
</tr>
<tr>
<td>(5) NC robots</td>
<td>4</td>
<td>12</td>
<td>39</td>
</tr>
<tr>
<td>(6) Intelligent robots</td>
<td>—</td>
<td>—</td>
<td>5</td>
</tr>
<tr>
<td>(7) (4) + (5) + (6)</td>
<td>281</td>
<td>326</td>
<td>1211</td>
</tr>
</tbody>
</table>

For our study, however, what is most important is that most NC machine tools and robots in the automobile industry were purchased in or after 1980, the year in which the peak of hourly output per worker was reached in this industry. This implies that these new machines have not helped save labour, or that their labour-saving effect has been more than offset by other factors. Our analysis in the next two sections will shed some light on this point.

3 SURVEY FINDINGS

Our survey was conducted in November–December 1983. The five largest automobile assemblers (Toyota, Nissan, Mazda, Honda and Mitsubishi), 22 major components makers and 30 small subcontractors in Hiroshima, Nagoya and Tokyo cooperated for the survey. A questionnaire form was sent to the companies of the first two groups. A follow-up visit was then paid to complete the form or to check and clarify completed forms.

The five assemblers accounted for 80 per cent of Japan's total automobile production in 1983, Toyota, Nissan and each of the other three producing 29, 22 and more or less 10 per cent each, respectively. The remaining 20 per cent was shared by six companies including two specialized truck and bus manufacturers. In the case of Honda, data were supplied only with regard to its Saitama and Wako plants. Purchasing, on an average, 70 per cent of their parts and components from other firms, each assembler has roughly 100–250 main component suppliers, who are organized into a group such as Toyota's Kyohokai. The component manufacturers we interviewed are all key suppliers to different assemblers.

To preserve the anonymity of the respondents, the data obtained are presented in Tables 6 and 7 in an aggregated form.

(i) The extent and purposes of application of microelectronic machinery

(a) The assemblers

Of the total numbers of NC machine tools (1255) and robots of playback and higher categories (3161) reported by the assemblers, 87 per cent and 77 per cent, respectively, belonged to Toyota and Nissan. Four assemblers introduced small numbers of NC machine tools (usually milling and drilling machines) between 1965 and 1970. Use of NC machines spread in the second half of the 1970s, especially after 1977. Two firms installed their first spot-welding robots in 1970 for experimental purposes but the robotization of various processes really began in the late 1970s, when underbody welding robots became available and the reliability of robots increased. Three assemblers introduced robots in their final assembly process in 1982. A fourth user did not specify the date when the application of robots in this process began. The assemblers, however, classified their robots in this process as material-handling robots rather than assembly robots in the proper sense of the term.
Some firms built playback robots in-house, about 40 out of 220 at one company. Such robots had rarely been reported to JIRMA. This implies that the JIRMA statistics cited in Table 5 somewhat underestimate the actual number of robots in Japanese industries.

According to a study conducted by the Confederation of Japan Automobile Workers' Union (JAW), five assemblers included in our survey had 1731 robots of playback and higher categories in summer 1981. Five others had 360 robots. If these figures are comparable with ours, the number of robots at the first group nearly doubled in two years. If we assume that the ratio of the second group to the first remained the same (roughly 20 per cent including Fuji Heavy Industries, which was left out of the JAW study), the assembly sector of this industry is estimated to have had approximately 4000 robots at the time of our survey.

One smaller assembler manufactured key components such as cylinder blocks and transmission cases using about 60 machining centres. The four other assemblers used NC machine tools mainly for trial production of components, die-making and production of key components for special models which were not mass produced. All five assemblers referred to the flexibility of such machine tools in explaining the primary reason for their application: those machines were helpful in diversifying models while maintaining high rates of capital utilization thanks to their shorter lead time. NC also guaranteed a higher precision of work and helped solve the problem of shortage of skilled workers, for example in die-making. It also enabled production of difficult-shaped dies that were impossible with conventional machines, and thereby integration of several parts into a single piece. In machining mass production items (parts and components), conventional special-purpose machines were much more productive, and therefore NC machines accounted for only marginal proportions of all machines on production lines (barely 1 per cent at large assemblers).

Table 6 shows that the assemblers use 80 per cent of their robots for spot welding, 10 per cent for arc welding and 7 per cent for painting. For material handling, simpler auto-loaders and unloaders (manual, and fixed- and variable-sequence manipulators) are used except where the work requires movements too complex for them. They cost much less than robots when they are purchased. More often than not, however, they are built by workers in their QC circles, as mentioned in the previous section. The reasons for the use of robots varied, depending on the area of application. As 95.8 per cent of the robots reported by the five assemblers were used for welding and painting, however, the main purposes of robotization in the Japanese automobile assembly can be summarized as (1) to increase flexibility of the production facilities, and (2) to solve or circumvent the problem of safety and health or work environment. Labour saving is of secondary importance, except in material handling. It should be noted, however, that robotization often has significant secondary effects. In both welding and painting, robots help improve the quality of work, through consistency. They also do away with the
air-cooling system in the painting shop, and help save considerable capital and energy.

Our interviewees explained the importance of the flexibility factor as follows. After the first oil crisis, the growth of the Japanese economy slowed down drastically. Competition among the automobile manufacturers over the share of the domestic market intensified. Uncertainty of the market increased. At the same time, owing to increased affluence in Japan, consumers grew more individualistic, demanding a wider range of choice. The car manufacturers had to be prepared to produce vehicles which complied with the tastes of individual customers. All these changes in the market conditions called for flexibility of equipment in coping with frequent model changes (long-term flexibility) and for recurrent production of a variety of small and medium-sized batches (short-term flexibility).

The importance of the factor of work environment, or safety and health, was explained as follows. As the standard of living improved, social consciousness of the work environment increased steadily after the late 1960s. Few young workers were now willing to take up dirty and strenuous jobs and the labour turnover rate was high in workplaces involving these. Also, the average age of Japanese workers was rising: contrary to the trend in Europe, the retirement age in Japan was extending from the conventional 55 to 60 and over. For both reasons it was necessary to reduce dirty and/or strenuous tasks. All five assemblers mentioned these factors as the primary reasons for introducing painting robots.

It is often argued that the diffusion of robots in Japanese industries accelerated after the price of the welding robot fell below 10 million yen. The average price of the playback robots shipped to the automobile industry was 9.6 million yen in 1978 and 8.6 million yen in 1982. In 1978 the assemblers paid, on the average, 3.3 million yen per worker. Since the cash remuneration (including the two bonuses a year) accounts for about 80 per cent of the total labour cost in the Japanese manufacturing enterprises with 5000 workers or more, the total labour cost per worker must have been about 3.9 million yen in that year and about 5.2 million yen in 1982 (the annual rate of wage increase was about 7.5 per cent). This implies that the average cost of robots declined from 2.5 times the average annual total cost of workers in 1978 to 1.6 times by 1982. However, certain types of robots cost much more than a welding robot, and tools and fixtures can be more expensive than the robot itself. Moreover, satisfactory operation of a robot requires an extremely strict quality control of workpieces, which implies additional capital investment in the previous production processes. It may not be an exaggeration therefore to argue, as a few interviewees did, that a consideration of working conditions sometimes prompted a firm to undertake robotization regardless of short-term economic calculations.

CAD/CAM had been used for about ten years, and especially intensively since the end of the 1970s, by four companies. (CAD had been in use since the mid-1960s.) Flexibility and reduced need for highly trained people were
<table>
<thead>
<tr>
<th>Machine/area of application</th>
<th>Motivation</th>
<th>Assemblers (5)</th>
<th>Component makers (20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of replies in order of importance</td>
<td>No. of replies in order of importance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1st 2nd 3rd</td>
<td>1st 2nd 3rd</td>
</tr>
<tr>
<td><strong>NC machines (1255/1156)</strong></td>
<td>Flexibility</td>
<td>5  — — 5</td>
<td>29 13 5 47</td>
</tr>
<tr>
<td></td>
<td>More regular or higher quality of work</td>
<td>— 1 1 2</td>
<td>18 14 12 44</td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td>— — —</td>
<td>8 1 5 14</td>
</tr>
<tr>
<td></td>
<td>Skill saving</td>
<td>— — 1 1</td>
<td>5 8 — 13</td>
</tr>
<tr>
<td><strong>Robots (3161/440)</strong></td>
<td>Flexibility</td>
<td>3 2 — 5</td>
<td>3 1 — 4</td>
</tr>
<tr>
<td>Spot welding (2520/40)</td>
<td>Safety and health (e.g. lighter labour)</td>
<td>2 3 — 5</td>
<td>2 4 — 6</td>
</tr>
<tr>
<td></td>
<td>More regular quality of work</td>
<td>— — 2 2</td>
<td>1 2 4 7</td>
</tr>
<tr>
<td></td>
<td>Automation of more complex work</td>
<td>— — 1 1</td>
<td>— — — —</td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td>— — 1 1</td>
<td>1 — — 1</td>
</tr>
<tr>
<td>Arc welding (299/164)</td>
<td>Flexibility</td>
<td>3 1 — 4</td>
<td>4 2 3 9</td>
</tr>
<tr>
<td></td>
<td>Safety and health/better work environment</td>
<td>2 3 — 5</td>
<td>3 1 3 7</td>
</tr>
<tr>
<td>Category</td>
<td>Objective</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Painting (209/10)</td>
<td>Work environment</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better/more regular quality of work</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Energy saving/capital saving in heat control</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Inspection (→/32)</td>
<td>More regular quality of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly (e.g. electronic</td>
<td>Labour saving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>components) (→/67)</td>
<td>Higher or more regular quality of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (e.g. material handling)</td>
<td>Labour saving</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Safety and health (lighter labour)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>More regular quality of work</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
1. Robots of playback category and above only.
2. The numbers of component makers' replies concerning NC machines are sums of replies given with respect to each of five categories of NC machines: machining centres, lathes, other metal-cutting machines, metal-forming machines, and other.
3. The first figures in parentheses in the first column indicate the numbers of machines installed by the assemblers and the second figures those installed by the component makers.

From our survey.
the principal reasons for its application. According to one company, the requirement of highly trained designing staff fell by one-third or one-fourth for a given amount of work. Designing work which used to take ten days could now be finished in half a day. Consequently, CAD/CAM enabled assemblers to put into practice what they had been hoping to do but forbidden by the technical complexity or the staffing constraints (e.g. a larger R&D programme).

(b) Major component manufacturers

Eleven of our sample firms in this group produced engine components and transmissions, six body parts, three electrical and electronic components and two plastic and rubber parts. Their size varied from just over 100 to below 8000 workers, except for firm Y which employed over 26000 workers. Four firms reported a decline in their workforce since the mid-1970s. At three of them the annual sales had been stagnant in real terms, while the remaining one had been enjoying a high growth rate, as will be discussed below in some detail. In total, 1156 NC machines and 440 robots were reported. Two firms (plastic and rubber parts producers) had no NC machine and five firms no robot. Firm Y owned 40 per cent of all NC machines and 17 per cent of all robots. Generally speaking, the use of NC machines grew with the firm size. This was not the case with the robot, except that three firms with fewer than 300 workers had a total of only eight robots.

In the same way as the assemblers, most component manufacturers applied their NC machine tools for trial production, die-making and manufacturing of small batch items, using conventional special-purpose machines for mass production. The positive correlation between the number of NC machines and the firm size seems to be explained by the greater variety of products that are produced by larger firms. Firm Y's dominant position as a user of such machines reflects the vast range of electrical and electronic car parts it produces. While spot welding was the most important area of robotization at the assemblers' plants, component manufacturers used playback robots mainly for arc welding and NC robots for the assembly of electronic parts and components. This difference is a clear indication of the division of labour between the two groups of firms. Another important area of application was material handling, although simpler equipment was used under normal circumstances.

The most frequent reason for the application of NC machines and robots was the same as at the assemblers'—the need for flexibility of production facilities (Table 6). A relatively small producer of electrical and electronic parts stated that the variety of its products had risen from about 1200 kinds to some 2000 within the last three years. The increased car models and frequent model changes expanded the list of replacement parts required. Of course, NC machines and robots were not the only means to meet these demands. In
the case of a firm stamping door panels, for example, it became necessary to change the die for its pressing machines fourteen to fifteen times a day because of the increasing differentiation of vehicles. To meet this need, the firm developed a quick die-changer, which reduced the die-changing time from 28 minutes in 1977 to 2.4 minutes by 1981 and raised the uptime of its machines from 28 per cent to 88 per cent of total work hours.

The second most important purpose of NC machine application was to attain higher and more regular quality of work. Component makers' quality consciousness grew partly because of the use of robots and partly for the purpose of more thorough implementation of the 'just-in-time system'. The work of a robot can be disrupted by irregularity in the quality of workpieces. A thorough implementation of the ‘just-in-time system’ does not permit an inventory of parts and components and therefore demands an absolute guarantee of their quality. The development of NC testing and inspection machines has made piece-by-piece inspection of parts and components economically feasible.

In this group, again, the new technology had been introduced to save labour only in relatively limited cases, because simpler and cheaper means are usually employed for this purpose. It is, however, important to note that both principal areas and objectives of application of the new technology change over time as a result of socioeconomic developments and of the progress made in the technology itself. According to firm Y, environmental considerations were predominant in the early 1970s, but flexibility became the primary objective towards the end of the decade.

Nearly half of the component manufacturers (ten out of 22) had CAD, although CAM was rare. Flexibility and skill savings were their common motivations. Some firms had installed such equipment during the 1970s, but its diffusion accelerated after 1980.

(c) Small subcontractors

The small firms included in our survey were second- and third-level subcontractors of automobile assemblers, namely subcontractors and sub-subcontractors of component manufacturers. Except for two firms engaged in plastic moulding, they were producers of metal parts. Their size distribution and the diffusion of NC machines and robots among them are summarized in Table 7. The table confirms the thinly dispersed distribution of microelectronic machines among small firms.

Nine out of eleven non-users of NC machine tools explained that such equipment was unsuitable to the nature of their products and to the pattern of their operation. Five firms were engaged in once-for-all production of small lots (sometimes only one piece) of miscellaneous products using general-purpose machines. Four other firms specialized in mass production of only a few items of relatively low precision, using automatic special-purpose
Table 7: Diffusion of NC machines and robots among small subcontractors

<table>
<thead>
<tr>
<th>Equipment installed</th>
<th>Size of enterprise (no. of workers)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-9</td>
</tr>
<tr>
<td>NC machines</td>
<td>7</td>
</tr>
<tr>
<td>Robots</td>
<td>—</td>
</tr>
<tr>
<td>Neither</td>
<td>4</td>
</tr>
<tr>
<td>Total number of sample firms</td>
<td>11</td>
</tr>
</tbody>
</table>

From our survey.

machines. Since their products were small in size and light in weight, no robot was necessary. In brief, these nine firms were working either to the left of Q1 or to the right of Q2 in Figure 3, Chapter I. The remaining two firms had been discouraged primarily by the uncertainty in securing orders sufficient to maintain a high rate of utilization of such equipment. This was mentioned by two firms as a secondary reason for non-application, while two other firms stated that the need for hiring electronics specialists was a secondary constraint.

While flexibility was the greatest attraction of such machinery to assemblers and major component manufacturers, this was not the case among small firms. The need for a higher precision of their product was the most common reason for using NC machines (twelve out of nineteen users). This seems to be somewhat related to the problem of shortage of skilled workers, which was mentioned as the primary reason for the application of NC machines by two firms and as the secondary reason by six firms. Shortage of skilled workers is more serious among small firms than among larger ones. The remaining five firms referred to quality control (two firms), labour saving, flexibility and study of 'mechatronics' (one firm each). Labour saving was mentioned as a secondary reason by five firms, and the possibility of unmanned operation during the night was mentioned by three users of wire-cutting machines. The two users of arc-welding robots gave the same primary and secondary objectives: labour saving and quality control.
Flexible Automation and Labour Productivity in the Japanese Automobile Industry

(ii) The employment impact of the new technology

(a) NC machine tools

The assemblers and most component producers felt that the NC machine tools helped increase productivity of capital by their versatility and short lead time, but did not save much labour. To save labour, special-purpose machines were far more effective, especially because workers at major companies in Japan operated a considerable number of different machines (cf Section 1(ii) above). Hence the only assembler that used a substantial number of machining centres for machining transmissions and other components limited their use to work areas unsuitable for special-purpose machines. The NC EDM and the wire-cutting machine were exceptions. These machines not only revolutionized die-making technique by easily handling complex shapes but made the unmanned night shift possible.

A majority of our interviewees at these firms discussed the subject in general terms without giving any precise figure, partly because large numbers of different NC machines were used under vastly different conditions. It was also pointed out that the machine–man ratio was almost incessantly changing depending on the market situation. A number of firms, however, gave more or less specific assessments of the labour-saving effect of NC machine tools. They are shown in Table 8, where component manufacturers are coded with capital letters A, B, C, etc. By and large, the data are consistent with the general view mentioned above.

An outstanding exception was firm A, producer of large diesel engines, which had 116 NC machine tools. The proportion of NC machines in the total number of machines was below 10 per cent. The firm estimated that these machines saved 360 production workers of different skill levels, while four engineers and four maintenance workers had to be added. For processing of bulky items, machines were organized into flexible manufacturing systems which operated 24 hours a day. Labour had been saved by integrating a number of processes of complex machining work into a single line. The total number of employees continued to increase as the business expanded. This company used no robot but 66 variable-sequence manipulators all built in-house.

While firm A’s experience suggests that the application of NC machine tools in a system can create a major impact on employment, it is interesting to compare it with the experiences of two other firms. At the already mentioned firm Y, labour productivity rose at a rate of 5 or 6 per cent every year (and the workforce grew by about 1200 workers). About 90 per cent of the productivity increase was attributed to ‘fixed automation’ based on transfer machines and to the rationalization of work organization. At a major rubber and plastic parts manufacturer, the annual sales expanded by a factor of 4.5 between the first and the second half of the 1970s and by 90 per cent during the first three years of the 1980s. Its workforce shrank by 25 per cent and by 15 per cent
Table 8: Some assessments of the labour-saving effect of NC machines, robots and CAD/CAM

<table>
<thead>
<tr>
<th>Firm code</th>
<th>No. of workers</th>
<th>Machine (no.)</th>
<th>Labour savings&lt;sup&gt;b&lt;/sup&gt; (no. of workers per machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5490</td>
<td>MC (32)</td>
<td>4 (Minus a total of 4 engineers and 2 maintenance workers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (40)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milling, etc. (44)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4700</td>
<td>MC (14)</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (55)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic-forming (1)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>4622</td>
<td>Grinder (3)</td>
<td>No impact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bender (19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pipe-cutter (8)</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3380</td>
<td>MC (48)</td>
<td>Possibly negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (17)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other (9)</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>2293</td>
<td>MC (8)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (16)</td>
<td>No saving</td>
</tr>
<tr>
<td>F</td>
<td>1200</td>
<td>MC (1)</td>
<td>1/3 (minus a total of 3 programmers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milling (3)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bender (1)</td>
<td>1/3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EDM/wire-cutting (3)</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>760</td>
<td>Boring (2)</td>
<td>1 operator and 2 gauge makers in total</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shaping (1)</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>671</td>
<td>MC (8)</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (6)</td>
<td>0.5–1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drilling (5)</td>
<td>?</td>
</tr>
<tr>
<td>I</td>
<td>113</td>
<td>Milling</td>
<td>No impact</td>
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<td></td>
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<td>Press (2)</td>
<td></td>
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<tr>
<td>a</td>
<td>160</td>
<td>MC (3)</td>
<td>Negative effect in machining more or less offset by labour saving in quality control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (10)</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>85</td>
<td>MC (1)</td>
<td>No impact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roll feeder (2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire-cutting (3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>68</td>
<td>Milling (1)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire-cutting (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>55</td>
<td>MC (1)</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire-cutting (2)</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>40</td>
<td>MC (3)</td>
<td>10–20% saving in preproduction and testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lathe (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milling (4)</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>18</td>
<td>Lathe (1)</td>
<td>2–3 workers' value</td>
</tr>
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</table>
Table 8 (contd)

<table>
<thead>
<tr>
<th>Firm code</th>
<th>No. of workers</th>
<th>Machine (no.)</th>
<th>Labour savings&lt;sup&gt;b&lt;/sup&gt; (no. of workers per machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>11</td>
<td>Lathe (3)</td>
<td>Skill saving, not labour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milling (1)</td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>4</td>
<td>MC (1)</td>
<td>Skill saving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EDM (1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Over 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire-cutting (1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.8</td>
</tr>
<tr>
<td>i</td>
<td>7</td>
<td>Lathe (4)</td>
<td>0.5</td>
</tr>
<tr>
<td>j</td>
<td>4</td>
<td>Lathe (1)</td>
<td>No impact</td>
</tr>
<tr>
<td>k</td>
<td>3</td>
<td>Lathe (2)</td>
<td>2.5–3 workers' value</td>
</tr>
<tr>
<td>l</td>
<td>3</td>
<td>Milling (1)</td>
<td>Work value increased</td>
</tr>
</tbody>
</table>

**Robots**

<table>
<thead>
<tr>
<th>Firm code</th>
<th>No. of workers</th>
<th>Machine (no.)</th>
<th>Labour savings&lt;sup&gt;b&lt;/sup&gt; (no. of workers per machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>4700</td>
<td>Arc welding (1)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plating (2)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Machining (2)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assembly (16)</td>
<td>0.9 (= 14/16)</td>
</tr>
<tr>
<td>C</td>
<td>4622</td>
<td>Arc welding (14)</td>
<td>0.3 (= 4/14), minus a total of 1 programmer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assembly (13)</td>
<td>0.7 (= 9/13)</td>
</tr>
<tr>
<td>E</td>
<td>2293</td>
<td>Arc welding (6)</td>
<td>Negative, but skill saving</td>
</tr>
<tr>
<td>G</td>
<td>760</td>
<td>Spot welding (11)</td>
<td>No saving</td>
</tr>
<tr>
<td>I</td>
<td>113</td>
<td>Arc welding (3)</td>
<td>Negative</td>
</tr>
<tr>
<td>J</td>
<td>680</td>
<td>Spot welding (6)</td>
<td>0.7 (= 4/6)</td>
</tr>
<tr>
<td>K</td>
<td>179</td>
<td>Spot welding (2)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arc welding (3)</td>
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</tr>
<tr>
<td>d</td>
<td>55</td>
<td>Arc welding (2)</td>
<td>0.7</td>
</tr>
<tr>
<td>m</td>
<td>214</td>
<td>Arc welding (7)</td>
<td>0.7</td>
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</table>

**CAD/CAM**

<table>
<thead>
<tr>
<th>Firm code</th>
<th>No. of workers</th>
<th>Labour savings&lt;sup&gt;b&lt;/sup&gt; (no. of workers per machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>15 (minus 2 maintenance-workers)</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>7</td>
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</tbody>
</table>

<sup>a</sup>Capital letters: component manufacturers; small letters: subcontractors.

<sup>b</sup>Usually in two shifts. Few firms gave estimates of the programmers and maintenance staff.

<sup>c</sup>Partially in FMSs, which worked on unmanned night shifts.

<sup>d</sup>Operated during the night without attendant.

From our survey.
during those two periods. No NC machine tool or robot was used. The labour savings had been realized in four ways: (a) increase in the use of transfer machines, (b) use of simple mechanical stoppers, loaders and unloaders, chutes and similar devices, (c) improvement in plant layout and elimination of unnecessary movements, and (d) development of a more efficient vulcanizing method. Apart from the last item, these are what major car assemblers did in the 1950s and 1960s (cf Section 1(ii) above).

As the numbers of machines owned by the small subcontractors are limited and as NC machines are usually introduced with little change in the other aspects of the enterprise, the impact of their new machinery can be more precisely assessed. Twelve out of the eighteen subcontractors who had NC machines provided some kind of estimate. The estimates are given in Table 8 in the section coded with small letters.

Two points immediately attract our attention. One is the relative popularity of the EDM and wire-cutting machines among small subcontractors, and their significant labour-saving effect which is attributable to the suitability of such machines for the unmanned night shift. The other point concerns the assessment of the merit of NC machines in terms of the value of work.

The processing charge paid to subcontractors usually increases with the introduction of NC machines. For example, a firm reported that the charge per piece of work done with NC machines was 100 yen, as compared with 40 yen in the case of conventional machines. Many proprietors of household enterprises do not want to increase their workforce, often because of their limited managerial capacity. Even if they wanted, it would be difficult for them to attract skilled workers. Thus the choice open to them is usually not between NC machines and workers, but between a smaller turnover with conventional machines and a larger turnover with NC machines.

Efficiency achieved with conventional machines has a lot to do with the new machines' impact on productivity, even at small firms. A firm with 160 workers reported that one worker was needed for every three NC lathes as compared with one for every ten special-purpose lathes. Moreover, a six-axis automatic machine was faster than a single-axis NC lathe. Another important influencing factor is the mode of application. This point has been already noted with reference to firm A's experience. Firms with fewer than ten workers knew that a single NC lathe could do little to increase productivity because the workpieces had to be reloaded before their two ends were processed. And yet, many of them (four in our sample) could not acquire more than one, either because of uncertainty in securing enough work or because of financial constraint. Installed machines were often seriously underutilized, so much so that one respondent felt that at about 80 per cent of the small firms he knew NC machines served the purpose of publicity only. It is true that small firms tend to keep different kinds of machines just in case need arises. Underlying this is the fact that small subcontractors are usually selected by their parent firms on account of the quality of their equipment.
Flexible Automation and Labour Productivity in the Japanese Automobile Industry 65

(b) Robots

The assemblers' welding lines were between 85 per cent and over 95 per cent automated at the time of our survey, the difference being explained partly by the amount and type(s) of work subcontracted to other firms. Three firms reported that the degree of automation had been 10–35 per cent lower before the introduction of robots, depending on the plant. Another firm reported that at its main plant spot welding had been 90 per cent automated before robots were introduced. Sometimes the rate of automation remained much the same after multi-spot welders had been replaced by robots. Where robots were introduced to do work hitherto done by workers, each welding robot replaced or substituted for, on an average, 0.5–0.7 workers per shift, depending on the company. In other processes, each robot replaced or substituted for between 0.5 (e.g. final assembly) and about 1.0 (painting) worker per shift.

At the assemblers' plants, we were told that 50 per cent or more of robots had replaced or substituted for 'fixed automation' machines such as multi-spot welders. If we assume that 0.6 worker was saved per shift and approximately 1.2 workers in two shifts where robots were introduced to do work hitherto done by workers, it is estimated that 950 workers were saved at these companies' plants (excluding two of Honda's plants left out of our survey) per shift \((3161 \times 0.5 \times 0.6 = 948)\) and 1900 workers in two shifts. Applying the same ratios to the estimated total number of robots in the automobile assembly industry as a whole \((4000)\), labour savings due to robots in this industry are estimated very roughly at 1200 workers per shift and 2400 workers in two shifts.

With respect to the automobile industry as a whole, the worker–robot replacement ratio might probably be 0.7, as the weight of the large assembler who reported the ratio of 0.5 diminishes. Indeed, there is a general consensus in Japanese industries regarding the ratio of 0.7. If we assume further that all the robots shipped to the automobile industry during the six-year period 1978–83 were in use at the end of 1984 (the statutory depreciation period for industrial machinery in Japan is seven years), then there should have been about 10 000 robots (Table 5). Let us further assume that 50 per cent of them had been introduced to replace or substitute for workers. Then, it is estimated that robotization had saved the industry 7000 workers by the end of 1984.

Such savings in direct production labour, however, are offset to some extent by the increasing need for programmers and maintenance staff. With reference to a body assembly (welding) line, one small assembler estimated that, with a constant daily production capacity of 950 units, the number of ordinary workers and supervisors fell from 386 to 302 (in two shifts) after the introduction of 62 robots (or 1.35 workers per robot), partly thanks to various other improvements brought about by the QC circles. In the meantime maintenance staff grew from 27 to 39 (0.2 worker per robot) and the
non-production indirect staff (e.g. programmers and R&D personnel) from 70 to 86 (or 0.25 worker per robot).

The component producers' assessment of the employment effect of robots varied considerably. The most positive assessment was that 21 robots in various processes had saved, on two shifts, seventeen machine operators, four unskilled workers and four skilled workers (firm B in Table 8). The differences in the assessments are attributable to (1) the area of application, (2) the previously attained level of automation (e.g. manual or automatic arc welding), (3) the mode of application or work organization, and (4) the rate of capacity utilization. At two firms, robots had not saved much labour because of underutilization. The situation was similar in a few other firms, which were still in a learning process. In the light of the data given in Table 8, the above assessment of the labour savings based on the coefficient of 1.4 in two shifts seems considerably to overestimate the reality.

(c) The overall employment impact

The assemblers and major component manufacturers believed that the overall employment impact of the microelectronic technology was marginal. Far greater was the influence of the following factors: (1) the level of production, (2) the product mix (more manual work was required for production of the higher class vehicles), (3) the design of cars, and (4) work organization, i.e. industrial engineering. All the assemblers also stressed that minor improvements at the workshop level originating from the QC circles and the suggestion scheme had greater cumulative effect on labour productivity than microelectronic technology. This is persuasive, particularly if one remembers the vast scale of workers' participation in such activities. At Toyota, for example, 1.9 million suggestions, or 38.8 per employee, were made in 1982. Of this total, 95 per cent were adopted by the company.

Nevertheless, it is clear from our analysis above that both robots and NC machine tools have created at least some labour savings. How has this been absorbed? Under the Japanese life-employment system the employers are cautious in recruiting additional workers even during a boom period as they have to be prepared to keep them during depression periods. If a firm wants to put more human resources into a certain area of activity, it will therefore first try to save labour somewhere else. In some cases, microelectronic equipment is one of the means to achieve this goal, i.e. 'to reduce the workforce on specific production lines'. The labour saved is deployed to do the new or additional work.

In this connection, it is necessary to recall what our analysis in Section 1(i) discovered, namely, the reversal of the trend of output per worker after 1980. To satisfy the increasingly luxurious taste of users and also to increase the value added per vehicle, the number of components (especially electronic ones) to be assembled has been rising and this has increased the work not only in manufacturing such components but also in final assembly and testing. For
this very reason, by 1981, the workforce at a leading assembly plant had declined to 34 per cent of the 1979 level. It then rose to 90 per cent by 1983, while the index of production per worker continued to fall steadily from 100 to 75 throughout the period. The body shape has become more complex rather than simpler. Partly for this reason, the number of spots to be welded on another company's car grew from 2000 in 1977 to 3000 in 1981, while the complex body shape forbade a further increase in the rate of automation (80 per cent). Two other assemblers reported a similar experience.

At the same time, one needs to note a paradoxical effect of the flexible microelectronic machinery. On the one hand, it reduces the cost of product differentiation through its versatility and short lead time. On the other, this encourages further product differentiation and shortening of the product cycle, and creates demand for more R&D, prototype production and organizational work with respect to a given level of annual automobile production.

(iii) Skill requirements and workers' attitude

It has been shown that one frequent motivation for the application of microelectronic machinery is related to skill savings. The skill-saving effect of the new technology is most conspicuous in the case of the NC wire-cutting machine. Unlike the machining centre, which requires difficult programming due to its three-dimensional operation, programming of this machine is so easy that one of the firms in the smallest size group hired a home management college student as a part-time programmer after the proprietor had given her a few days' on-the-job training. The machine operated during the night without any attendant. One entrepreneur elaborated upon the skill-saving effect of NC machines with reference to the machining centre, as follows. The new machine needed about 40 per cent more time to do the firm's work as compared with conventional machines operated by a worker with ten to fifteen years' experience. The productivity of a worker with one year's experience, however, was one-third or one-fourth that of the experienced worker's when they worked with conventional machines. The difference came down to only 40 per cent when they worked with a machining centre.

Skill saving is not the same thing as 'deskilling' in the Japanese context. Japanese industrialists use the term 'skill saving' when the machine can do the work which requires a skill level higher than what is available (i.e. the skill level of the existing or accessible worker(s)), including what has hitherto been impossible (e.g. extremely complex-shaped die-making). 'Deskilling' of workers is unlikely to happen, because at least simple maintenance and repair work on the new machinery is usually a part of the duties of its operator, although for very small enterprises the machinery supplier very often provides such services.

Just as Japanese workers were expected to acquire multiple skills for 'fixed automation', therefore, today's 'flexible automation' demands that they acquire knowledge of 'mecha-tronics' (i.e. mechanics plus electronics). To
keep up with the technological trend, many workers take correspondence courses and other crash training courses offered by different institutes, notably those organized by an industrial newspaper company and prefectural governments. Employers usually subsidize part of the fees, as they do in many other areas of study. In-plant introductory courses are also common, guided by experts from inside or outside the company. Once the application of new technology has been decided upon, knowhow concerning the new equipment is acquired by supervisory staff (e.g. line chiefs) through courses offered by the machinery supplier. In turn ordinary workers receive guidance from the supervisory staff on the job.

Adjustments to the formal vocational training system have also got under way. Nissan's training school for new school leavers now has electronics as a third area of study after automobile engineering and mechanical engineering. Such company training schools at the high-school level have played an important role in securing middle-class manpower in the postwar Japan. In order to meet the need for higher-level personnel in the 'age of mechatronics', some companies are now planning to set up a two-year vocational college.34

Not all the workers affected have been happy about the loss of the job which they were used to. Older people sometimes find it difficult to adapt themselves to the new situation because of their limited capacity to absorb fresh technological knowledge. Such workers are transferred to more conventional posts, including those in the non-production category. Some of them leave the company and launch their own small enterprises. However, there has been no labour dispute about microelectronic innovation. Our interviewees attributed this to a number of factors. First, their industry kept growing, although at a slower rate than before. Second, job security was more or less assured to every existing worker by the social tradition against the dismissal of workers, while the workers are flexible and mobile, either geographically or interoccupationally. Third, consultation with workers took place as a matter of routine procedure whenever innovation was planned, so much so that some firms let workers choose robots to be installed in their workplace. Fourth, most robots had been installed to reduce dirty and/or strenuous work, and robots often opened up new, more creative types of work. Workers were, however, watching future developments carefully, especially the potential of final assembly robots. At one company, workers were said to have been concerned about the possible appearance of 'unmanned factories' and the introduction of robots into such easy workposts as suit middle-aged and older workers. However, none of our interviewees felt this was going to be a real problem. In the automobile industry, they were unable to think of many components suitable for 'unmanned factories': for one thing most auto-parts and components were too small for them, except for such items as large diesel engines for trucks.

Representatives of a company union and of the JAW confirmed the authenticity of company representatives' statements summarized above.
Workers were naturally concerned about alternative job opportunities and retraining, but they were optimistic 'because close consultation with the employer on such matters has been a time-honoured practice in Japanese industries'.

(iv) Constraints on the diffusion of the new technology

Three assemblers reported that recruitment and training of sufficient maintenance staff was one of their main concerns. Lack of standardization of robots, produced by different robot manufacturers added to the problem. Moreover, robots were still not entirely reliable. Occasionally their controlling system failed and let them make an unexpected movement. For this reason at least one assembler avoided installing them in lines where workers had to work alongside them.

Component manufacturers had some difficulty in using NC machines and robots: nine in maintenance, two in the development of software and another in the actual operation of such equipment. One of the firms which had maintenance problems, however, stated that the latest equipment was easier to use because there was a built-in problem indicator. On the other hand, the very fast progress of microelectronics itself made some firms hesitant to adopt new equipment because it implied a great risk in investment.

A few small subcontractors were unable to secure enough work to maintain a high rate of utilization of the equipment, and one firm had difficulty in programming the work of its NC milling machine. The two users of arc-welding robots reported that the satisfactory operation of these robots presupposed a far greater regularity in the quality of the workpieces than before, which required, in turn, improvement of equipment in earlier production processes. One of them did not want to invest for this purpose and sometimes laid off robots, letting workers take their place. Probably similar experiences at other plants prompted one of the non-users to say that 'robots are not for small firms'.

It may sound odd that the smaller firms reported a problem in the use of microelectronic machinery less frequently than the major firms. This seems to be largely explained by the fact that the former firms are less rigorous in using their production facilities, partly because of their looser bookkeeping practices. For example, many of them are less worried about low rates of capacity utilization and long downtime than larger firms.

Regarding prospects for the future, the increasing diversity of vehicles and the shortening life of individual models would encourage application of NC machines and robots. Improvement of the integrated circuit (IC) would simplify the programming and operation of such equipment and thereby reduce the (older) workers' psychological inhibitions. The largest potential area for the application of robots lies in the final assembly process. Most interviewees felt that if sufficiently advanced and low-cost robots were to appear to do the final assembly, which is the most labour-intensive process at
present (see Annex), the scale of recruitment of young workers might be reduced considerably.

Office automation may have a similar, but even greater, effect. It is suggestive that a rubber and plastic moulding firm had been cutting the number of administrative office workers by over 10 per cent every year through office automation. Simplification and standardization of the designing process and application of the CAM had reduced the designing staff from some hundred people to ten in fifteen years, despite the considerable growth of annual sales. The importance of the labour-saving effect of office automation was also stressed by a firm with about 600 employees. The number of administrative workers at this firm was fifteen at the time of our survey and the interviewee estimated that over 30 workers would have been needed without computerization of office work. Since a representative of a large assembler believed that Japanese firms were five to ten years behind their North American competitors with regard to office automation, there seems to be a great source of labour savings here in the near future.

It should also be noted that so far the impact of CAD/CAM has remained marginal because a majority of users are still in a learning stage. Once this phase is over, its impact will grow.

4 SUMMARY AND CONCLUSIONS

The oil crisis of 1973–74 caused a shift in the main objective of investment from labour saving through 'fixed automation' to the development and production of fuel-efficient, low-pollution cars and to 'flexible automation' to cope with the changeable and increasingly diversified demand. A process of dramatic labour productivity increase ended by the beginning of the 1970s. Over the next ten years, output per work hour in the industry doubled (compared with an eighteen-fold growth over the five-year period 1965–70), but it declined somewhat after 1980 when the diffusion of microelectronic machinery began to accelerate. This implies that the labour-saving effect of these machines has not been large enough to offset the increase in the amount of work put into each vehicle produced.

In the large-scale sector of the industry, the most frequent purposes of introducing NC machines and robots have been to secure a greater flexibility of equipment, higher and/or more regular quality of work, and the safety, health and work environment. The first two are related to increasing product diversity, more frequent model changes and the spread of the 'just-in-time system'. To save labour, firms usually look to conventional special-purpose machines and simpler automatic devices.

The labour-saving effect of NC machines and robots varies depending on a number of factors: (1) the degree of automation achieved before the introduction of the new technology; (2) work organization, plant layout and workers' skill level, which influence the number of machines tended by a worker; (3) the degree of precision or difficulty of the work assigned to the new equipment; and (4) the product market situation and the programmer's training
level, which affect the rate of utilization of the equipment. In the Japanese automobile industry, it has been limited for a number of reasons.

The Japanese automobile industry had reached an extremely high level of automation before the advent of microelectronic machinery. Consequently such machinery has been used, more often than not, to replace or substitute for conventional ‘fixed automation’ equipment, which is more labour-saving. Where it is introduced to do work hitherto done manually, the labour-saving effect tends to be limited because Japanese workers tend many machines.

Whatever the amount of labour savings achieved, these have not resulted in a dismissal of workers, partly because in many cases labour savings are sought in order to overcome the problem of recruitment or to do additional work while avoiding or minimizing growth of the personnel. Also, flexibility of microelectronic technologies tempts firms to increase the degree of product differentiation and R&D work (e.g. designing and prototype production) for each product, rather than reduce manpower requirements by restraining the increase in the volume of work. Since this happens with respect not only to the model of vehicle but also for numerous parts and components, the cumulative quantum of this effect is considerable, and this seems to be part of the explanation for the recent increase in work hours worked per vehicle.

In the small-scale sector, a large number of NC machines, widely and thinly dispersed among enterprises, remain underutilized. This is one of the explanations for the limited negative employment effect of NC machines in Japanese industries (plural because the phenomenon is not confined to the automobile industry). There are, however, some small enterprises which use similar machines ingeniously. With adequate marketing and technological capabilities, they programme their machines better than their parent firms expect and earn greater profits than the latter budget for. In their case, the new technology provides a solution to the problem of shortage of skilled workers and thus reduces constraints on business expansion (in terms of the amount of value added).

In the near future, there seems to be considerable scope for labour saving through microelectronics-based office automation. If efficient final assembly robots should become available at a low cost, they might also create a significant impact on the labour requirement in this industry. All these technological developments may reduce the scale of recruitment of new school leavers. The process will take time. In the near future, much more serious may be the impact of the internationalization of the industry’s operation, namely, the construction of overseas plants by Japanese automobile companies. Another cause of concern should be the increasing competition with the automobile industry of the Republic of Korea, which is emerging rapidly in the international market.

ACKNOWLEDGEMENTS

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Annex: Man-hours worked per vehicle (small passenger car) by process

A. Production processes

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<thead>
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<th>Year</th>
<th>Metal-forming</th>
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<th>Final assembly</th>
<th>Total</th>
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B. Supporting activities

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*Includes casting, forging, stamping and heat treatment.

From Ministry of Labour: Ródô Seisan-sei Tôkei Chôsa Hôkoku (Statistical Survey on Labour Productivity), various years.

NOTES

1 For some time after the Second World War, the main products of the Japanese automobile industry were trucks and buses as well as low-cost multipurpose three-wheelers. The annual production of four-wheelers (111 066 units) surpassed that of three-wheelers (105 409 units) in 1956, and for the first time in 1968 the annual production of passenger cars (2.06 million units) exceeded that of trucks (1.99 million units). Production of three-wheelers reached its peak in 1960 (278 032 units) and declined quickly thereafter (42 944 in 1965 and 11 673 in 1970). It ceased in 1974. Our study is concerned exclusively with four-wheeler production.

2 From the above, it is clear that neither the number of vehicles produced per worker nor the number of hours worked per vehicle is an accurate indicator of labour productivity. Even so, the recent trend of these variables may also suggest that the Japanese automobile industry is approaching a limit where further labour saving is economically difficult with conventional production and product technologies, with the possible exception of the final assembly process.

3 Ministry of Labour: Ródô Seisansei Tôkei Chôsa Hôkoku (Statistical Survey on Labour Productivity), various years.
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7 See Oono (1978), pp. 14-15. Sakichi Toyota was one of the greatest inventors in prewar Japan. His low-cost automatic weaving loom helped the Japanese weaving industry in its export drive after the First World War. It was equipped with a device to stop the loom when a defect was detected in the yarn. Toyota Motor Co. was founded by his son.
8 Showa Dōjin-kai (1958).
9 This would not only increase the workers' value in the company, but also build up a stronger base for their later career: Japanese blue-collar workers have a very high propensity to start their own business (often as subcontractors) after years of experience as an employee (cf Watanabe, 1970).
12 Tomiyama (1973), pp. 51-52 and 67-68.
14 For a detailed study of this process and the hierarchical structure of the Japanese subcontracting system, see Susumu Watanabe: 'Inter-sectoral linkages in Japanese industries: A historical perspective,' in Watanabe (1983), pp. 31-43. See also Wada (1976) for Nissan's experience.
15 Tomiyama (1973), pp. 97-110. Japanese companies use the QC circle and the suggestion scheme partly as a means of job humanization, as they provide opportunities to think and take initiative for workers who would otherwise follow a predetermined sequence of work at a given pace (time cycle) mechanically. The prevalence of these systems in the large and, to a lesser extent, the medium-sized sectors of Japanese industries seems to have a lot to do with two institutional elements of Japanese society. One is the historical tradition of group responsibility sharing, which provided a basic foundation for the feudal regime of the Tokugawa Shogunate (1605-1868). Under this regime, every five households in both urban and rural areas were organized into a group for administrative and taxation purposes. Land tax and other duties were to be borne collectively by the member households. In a considerably relaxed form this tradition has survived as ‘Tonarigumi’ for mutual assistance in daily life among neighbours. In the QC circle one can clearly recognize a trace of this tradition. The other institutional factor is the life-employment system. It would be difficult to expect employees to spend extra hours after work searching for ways to improve their own or their group’s performance for modest direct (indirectly, they are rewarded with larger biannual bonuses and faster wage increases as the company prospers in business thanks to their contribution) material incentives if their entire professional career were not vested in the company and if they were not assured of job security. The very fact that neither the QC circle nor the suggestion scheme is common in the smaller sectors of industries seems to support the above interpretation: the life-employment system is much less prevalent in this sector, partly because of the employer's own insecurity and partly because of workers' greater mobility.
16 Tōyō Kōgyō (1972), pp. 400-401.
17 The concept of the 'just-in-time system' dates as far back as 1936, when Toyota was starting its business in the automobile industry: 'Kiichiro Toyoda (one of the founders of this business line for the Group) put up the motto 'Just in time' on the wall . . . and cautioned his staff by saying that it was not intended to urge them to finish their work in time but to produce just enough and avoid producing earlier than scheduled . . .' (Toyota Jidōsha Kōgyō, 1978, pp. 64 and 186-87). The
philosophy underlying this system is that the workers obtain just the right quantities of the right kinds of parts and components at the right moments, to avoid stockpiling along the production lines. This minimizes both the cost of inventory carrying and the space required for that purpose. In order to achieve this goal, work at a point of the production process needs to be done strictly according to the orders received from the next stage of the work sequence. The whole process starts from the final assembly line, and the required kinds and quantities of workpieces (parts and components) are communicated backwards all the way down to the casting, forging or stamping shops (cf Figure 2, Chapter I) by means of a kind of order sheet, which is called 'Kamban'. (Strictly speaking, therefore, it is wrong to say ‘Kamban system’.) This small piece of paper synchronizes work in all the production processes.

20 Oono (1978).
22 Information supplied by the Japan Machine Tool Builders Association (JMTBA).
25 Seventeen major component producers were contacted through the assemblers (three to five each) and five through the Japan Auto-Parts Industries Association (JAPIA). The latter firms were selected by considering their known enthusiasm for microelectronic technologies and their importance in the auto-parts manufacturing industry. The small firms in the third group were contacted through branch offices of the People’s Finance Corporation, which is an official bank specialized in financing enterprises with fewer than 50 workers, and the Aichi Prefectural Economic Research Institute.
27 For example, when Toyota put its Corolla on the market in 1966, it was a sedan with an engine of 1100 cc. Today, it can have an engine of 1300, 1500, 1600, 1800 or 2200 cc, and its body type can be a sedan, lift-back, hard-top, van or coupé. Although 660 000 units of the Corolla were produced in 1982, they were divided into some 4000 varieties if minor differences in specifications such as the colour and interior accessories are counted. (Theoretically, some 10 000 varieties are possible.) Similarly, Mazda’s Capella was produced in some 2700 varieties in 1983.
28 JIRMA Survey for 1983.
30 See Chapter 2.
31 This partly due to the less attractive conditions of work (job insecurity arising from greater insecurity of small businesses, less generous retirement bonus, etc.) and partly to the mentality of those workers who choose a job in this sector (rather than are forced to accept it because they failed to get a job elsewhere), preferring, for example, opportunities for more varied experiences at different firms to life employment at a major company.
32 In a survey by the Ministry of Labour, 78 per cent of the respondents mentioned this as their motivation for the application of microelectronic machinery (Japanese Government, Rōdō-shō; 1983, section of reference material p. 163).
33 On the difference between Japan and the United States in this respect, see NAE and NRC (1982), p. 102.
34 Nihon Keizai Shim bun (Tokyo), 15 January 1986 (morning).
35 At the first Japan–Europe Industrial Symposium (Bedbaek, Denmark, December 1983), the president of the Japan Federation of Metal Workers’ Unions (ZEN-KIN DOMEI) declared that in Japan ‘not many problems have been caused in respect to the employment involved in the technological innovation’ and referred to ‘smooth job reclassifications or reassignments practised in the respective
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Many authors in the 1970s argued that the new technology would encourage the vertical integration of assemblers and major component manufacturers and thus deprive small subcontractors of their business. In retrospect, their expectation did not materialize. Neither the assemblers nor major component manufacturers in our survey had reduced subcontracting. The authenticity of their statements to this effect is clear in the light of the macro-level evidence. Between 1975 and 1981, the numbers of establishments with 1–49 workers increased over 21 percentage points, and those with 50–299 workers by 15 percentage points, according to the Establishment Census. In the meantime, the proportion of subcontractors in the total of enterprises with fewer than 300 workers rose from 86.2 per cent in 1976 to 87.7 per cent in 1981 in the transport equipment industry (White Paper on Medium and Small Enterprises for 1983, p. 163).

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Minami, Ryoshin (1973): The Turning Point in Economic Development: Japan’s Experience (Tokyo, Kinokuniya).


Nihon Jidōsha Kōgyōkai (Japan Automobile Manufacturers Association (JAMA)): Jidōsha Sangyō Kanren Tōkei (Statistics related to the automobile industry), various years.
CHAPTER IV

Microelectronics, Employment and Labour in the United States Automobile Industry

Bruce T. Allen

This study consists of five sections. Section 1 reviews the structure and trends in the automobile industry since the late 1960s in order to examine the background for the adoption of flexible automation. Section 2 deals with the extent of diffusion of NC machine tools and robots, as well as reasons for their application and non-application. Section 3 examines the applications of robots in different production processes. Sections 2 and 3 also contain an analysis of prospects in the future. Section 4 examines the employment implications of robotization and the response of the industry's principal labour union. This includes a brief discussion of the structure of bargaining and negotiations and of how robot-related issues have been fitted into the bargaining agenda. Section 5 is devoted to a summary and conclusions.

Although our enquiry is focused on the automobile industry of the United States, it is sometimes impossible to separate it from the Canadian part of the 'North American' automobile industry, which emerged from the 1965 trade agreement between the two countries.

1 STRUCTURE AND TRENDS OF THE INDUSTRY

Microelectronic production technologies spread in the North American automobile industry in the context of even more important changes in the industry. Indeed, the adoption of robotics is due largely to changes in the industry's circumstances. The response of the companies and workers to it cannot be understood independently from their history and characteristics. We begin with a brief description of the industry in the late 1960s.

The industry is a case of oligopoly with differentiated products and annual changes in product design, the four largest producers (General Motors, Ford, Chrysler and American Motors) accounting for over 99 per cent of the total output in the United States. General Motors (GM) has regularly produced over 50 per cent and has been the price leader. The clearest evidence of the industry's market power is its profit rate, which regularly exceeds the average for the manufacturing sector as a whole, while average hourly earnings of
production workers in this industry are about 40 per cent more than the average of all manufacturing industries ($3.45 against $2.45 in 1965, and $11.6 against $8.50 in 1982).³

Both production and employment in this industry fluctuate cyclically (Table 1), major changes in the latter following those in the former. Increasing penetration of imports and technological progress have intensified the down-

<table>
<thead>
<tr>
<th>Year</th>
<th>Production ('000 vehicles)</th>
<th>% of imports in the total sales</th>
<th>Employment ('000 workers)</th>
<th>Value added per hour worked (total production workers)²</th>
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<tr>
<td></td>
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<td>(3)</td>
<td>(4)</td>
</tr>
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<td>n.a.</td>
<td>389.4</td>
<td>699.6</td>
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</table>

²Excluding imports from Canada.
³SIC 3711: Assembled motor vehicles and auto bodies.
⁴Until 1971 the data include: SIC 3714: Motor vehicle parts; SIC 3694: Engine electrical equipment; SIC 3519: Internal combustion engines, not elsewhere classified. Since 1972 they have also included: SIC 3465: Automotive stampings; SIC 3592: Carburetors, engine valves and related stampings; SIC 3961: Lead storage batteries. The data for SIC 3711 overstate assembly employment, since several assembly plants (e.g. Oldsmobile Plant No. 1 in Lansing MI) also produce parts within the same establishment.
⁵Value added in constant prices, including both assembly and component manufacturing.

(1)–(2) from Automotive News, 1983 Market Data Book.
ward trend of employment in recent years, although a recovery in production in 1983 helped regain employment to some extent. Productivity (value added per work hour) grew 4.5 per cent a year between 1957 and 1966, but the growth rate fell to 2.9 per cent between 1965 and 1973 and 2.4 per cent between 1972 and 1981. Fragmentary evidence indicates a higher rate of productivity growth since 1981.

The automobile industry in the United States underwent three major environmental changes after the mid-1960s. Since 1966, cars sold in the country have been subject to federal safety requirements. In 1980, these requirements were estimated to add $300-400 to the cost of an average new automobile. The oil shock of 1973-74 made users conscious of cars' efficiency in fuel consumption. This has been reinforced by a recent regulation which requires that each vehicle maker achieve a 'corporate average fuel economy' of 27.5 miles per gallon by the 1985 model year.

The consumer response to higher fuel prices has been to buy compact and subcompact cars, whose share in the national market rose from 8 per cent in 1969 to over 50 per cent by 1980. (The percentage slightly declined to 49.3 per cent in 1982.) The manufacturers' response to higher fuel prices has been to introduce smaller car lines and to 'downsize' the whole range of their product mix. This has an important employment implication, because less labour is needed for assembly since components are smaller, lighter and fewer. They have also increased use of lighter, high-strength steels, aluminium and plastics. The four-cylinder engine typically used in subcompact cars now incorporates less than half the cast iron that was in the V8 that predominated in the late 1960s. Front-wheel drive, which replaces transmission, propeller shaft and differential gears with a single transaxle, became the standard configuration for compact and subcompact cars after 1978. Unibody (frameless) construction was rare before 1970. By 1984, it had replaced body-on-frame designs on 75 per cent of all cars except the largest. It is expected to become universal by 1990. In addition, styling is more influenced by aerodynamic considerations, and the power train and its components are becoming more fuel efficient.

A third, even more important change is the growth of imports. By 1971, imports (except those from Canada) had exceeded 15 per cent of the United States market. The origin of imports shifted increasingly from Europe to Japan. One result has been the closure of three out of four assembly plants on the West Coast, where domestic small cars became less competitive and where the market share of imports rose more rapidly. In response to pressures from the automobile workers' union and from most domestic firms (General Motors is an exception), the Government negotiated with Japan for voluntary limitation of car exports to the United States. Japanese cars became popular because of their lower prices and higher fuel efficiency. Another important feature is their quality. Since 1978 there has been a widespread perception that they offer 'fit and finish' superior to the North American-built products.

The industry has responded to these developments in different ways.
Changes in the size and design of the vehicles have already been mentioned. The assemblers were unwilling to give up the still substantial fraction of market that wanted larger and more traditional cars or the minority that wanted high-horsepower 'specialty' cars. Consequently, the industry's product line became apparently more diverse, with subcompacts, small cars, large cars and 'sporty' cars. The number of separate product classes tabulated by Ward's Automotive Yearbook rose from 41 in 1970 to 51 in 1981. At the same time, the market became slightly less concentrated; the Hirfindahl index based on the market shares of the top ten 'models' fell from 0.0369 to 0.0227 over the period. In principle, this greater diversity of products and shorter lives of individual models should encourage use of flexible microelectronic technologies. As we shall see later, however, diffusion of such technologies has been due more to other factors in the case of the North American industry. In many respects, the product diversity is more apparent than real, and is offset by a continuing search for 'commonality'—i.e. for components that can be shared by different models.

Another response to the new industrial environment has been organizational. Virtually all new or rebuilt assembly plants have adopted the 'just-in-time system'. In some cases, this means replacement of rail transport by more frequent and smaller truckload deliveries. In other cases, it means relocation of a company's supply facilities into an integrated plant complex, as has been the case with General Motors' Buick City at Flint, Michigan. Sometimes, suppliers have been urged, or nearly forced, to move their plants near the assembler's plant, as has happened at some of General Motors' Delco plants in Indiana. The primary motivation for adopting the system is the reduction of inventory costs. A secondary purpose is the increased manageability of plants where workers and their operations would otherwise be hidden from each other by tall stacks of stocked parts.

In the meantime, the assemblers began to revise their purchasing policy. An important issue in the 1984 contract negotiations concerned parts production outside the United States. Independent suppliers were notified that their costs must be kept down. Assemblers' supply departments have been threatened with discontinuation if they are not competitive with outside suppliers.

One final change worth noting concerns labour relations and personnel policy in this industry. Most hourly (blue-collar) workers employed by the automobile companies and larger parts suppliers are represented by the United Automobile Workers (UAW). Wages are adjusted annually for anticipated changes in productivity (the 'annual improvement factor') and quarterly for changes in the cost of living (COLA). An employment contract typically runs for three years, at the end of which the adjustment factors are renegotiated, the entire schedules shifted up and new fringe benefits (e.g. paid holidays, dental insurance) added or terms changed. As early as 1950, the UAW declared that higher real earnings depended on higher productivity. In 1971, workers at two General Motors Assembly Division plants struck over what in the end turned out to have been a disagreement concerning an
increase in the speed of their assembly lines. In the search for causes and solutions, it became clear that a large number of workers wanted more control over their work, and more influence on decisions that were made at the plant. Workers were paid to do what they were told, and they were told very little. The grievance mechanism was really a buffer between the workers and the management.  

The 1973 contracts provided a basis for change. The union and the companies agreed to make sustained, plant-level efforts to bring blue-collar employees and managers together in teams to solve problems. Much was written at that time about how industrial work had allegedly become 'alienating'. Employees' attachment to the companies and their goals of productivity and cost competitiveness was tenuous at best, and local industrial relations were often much more antagonistic than those between the UAW and the companies' collective bargaining staff. Part of the changes that were to come about stemmed from the availability of Japanese and Swedish practices as models. However, the major impetus was simply the workers' and plant and personnel managers' frustration with relations that had grown indifferent, and at worst hostile. A student of the history of industrial relations in the United States would not be optimistic about prospects for these efforts; structures similar to what is emerging existed before the 1930s largely to allow employers to avoid unionization. Despite the union's official policy favouring higher productivity, efforts to this end are often suspected at the local level as a device for taking away jobs.

Under the names Quality of Work Life (GM/UAW), Employee Involvement (Ford/UAW) and Quality Action Teams (Chrysler/UAW), hundreds of small employee/manager teams were formed. The effort required the help of professionals and consultants, and training; early sessions were unproductive and seemed futile; attitudes of managers, local union officers and workers all had to change. Summarizing his company's experience, a General Motors vice-president acknowledged that the way had not been easy, and that QC circles were not for everyone—but that where they had worked, they had led to higher productivity, better-quality output, better working conditions, or simply an improvement in relations between managers and employees. Unionists' opinions are sharply divided. Some complain that the programme has been used only to increase output and to eliminate jobs, and a few major programmes have been abandoned. However, many local union officials and plant managers have expressed dismay that Quality of Work Life (QWL) programmes might disappear.

The major plant conversions in which robotics was involved consequently took place after workers' and union participation increased. While both the permissive attitude of the national union and the threat of foreign competition also helped, this change in the local industrial relations environment reduced resistance to the technological change. Whatever the ultimate fate of the new industrial relations climate—or however extensive or limited the changes have really been—few have been heard wanting to go back to the old ways.
2 DIFFUSION OF NC MACHINE TOOLS AND ROBOTS

(i) NC machine tools

Numerical control technology was developed at the Massachusetts Institute of Technology, largely with the support and at the request of the United States Air Force. The initial demonstration was in 1954. Commercial introduction took place between 1954 and 1963. By 1963, the automobile industry had installed some 194 NC machine tools. Table 2 gives data on NC machines installed in the automobile industry and metalworking industries in general. With regard to many types of machines, the percentage of NC machines more than doubled between 1977 and 1983. However, the automobile industry lags behind other metalworking industries in the adoption of NC, except for two categories. When production runs are long—as they are in the North American automobile industry—'fixed' automation with conventional machines is more economical. One immediate implication is that we should expect to encounter NC in the automobile industry primarily where production volumes are small. In fact, we do. The three largest assemblers are increasing their use of NC for the manufacture of dies for stamping sheet-metal body parts as rapidly as possible. With NC machines, machining of such dies can be done directly from digital data supplied by computer-aided design (CAD) of the body panels. One manufacturer stated that the sheet-metal parts for a 1986 model were all being designed on CAD terminals, and that about 25 per cent of this allowed a direct interface between produce and die design.

It is clear that the integration of CAD and NC die machining will have substantial effects on the preproduction process. Engineering draftspeople will be the hardest hit in terms of job loss. The use and storage of multiple templates will no longer be required. Representatives of two car makers who now contract out substantial fractions of their tool and die work said that their companies would have to maintain some outside tooling, but that they were not confident that the independent tooling shops could maintain the necessary degree of automation and co-ordination with the car producers. Greater, but not total, integration of tool and die work is thus likely.

Most other applications are for work of small to medium-size batches. One company reported that it used NC machines at both ends of the car’s life cycle: for the trial production of parts for new models and for production of replacement parts for obsolete models. In the latter case, NC machines help avoid several years’ inventory of parts or intermittent use of skilled labour for production of replacement parts. Either way, there is a saving. One maker of power-train parts for heavy trucks stated that much of the company’s NC equipment was dedicated to many runs of ‘few of a kind’ parts.

We encountered relatively few high-volume applications of NC machines. Still, one component supplier used them in machining ball-joint suspension parts, rack-and-pinion steering parts and engine valves. Another firm applied
Table 2: Diffusion of NC machines in the United States automobile industry* and other metalworking industries, 1978 and 1983

<table>
<thead>
<tr>
<th>Machine category</th>
<th>1978</th>
<th>1983</th>
<th>All metalworking industries 1983</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>No. of NC machines</td>
<td>% of all machines</td>
<td>No. of NC machines</td>
</tr>
<tr>
<td>* <strong>Metal-cutting machines</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turning machines (lathes)</td>
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<td>Boring machines</td>
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<td>1.4</td>
<td>101</td>
</tr>
<tr>
<td>Drilling machines</td>
<td>105</td>
<td>0.6</td>
<td>246</td>
</tr>
<tr>
<td>Machining centres</td>
<td>236</td>
<td>100</td>
<td>580</td>
</tr>
<tr>
<td>Milling machines</td>
<td>66</td>
<td>0.9</td>
<td>314</td>
</tr>
<tr>
<td>Grinding machines</td>
<td>—</td>
<td>—</td>
<td>107</td>
</tr>
<tr>
<td>Thermal cutting machines</td>
<td>—</td>
<td>—</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>—</td>
<td>—</td>
<td>831</td>
</tr>
<tr>
<td>* <strong>Metal-forming machines</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punching and shearing machines</td>
<td>43</td>
<td>1.8</td>
<td>223</td>
</tr>
<tr>
<td>Bending and forming machines</td>
<td>20</td>
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<td>200</td>
</tr>
<tr>
<td>Other</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

*Virtually all data in this table pertain to SIC 371, and do not cover subindustries such as auto-parts stampings and automotive electrical equipment.

From 12th and 13th American Machinist Inventory of Metalworking Equipment, in American Machinist, December 1978 and November 1983, respectively.
NC extensively in its ring production. At least one car maker has been able to substitute NC-guided glass cutters for complicated and expensive templates in producing windshields.

Although the diffusion of NC machines is still limited, they are likely to spread more widely. Each car maker's products are likely to become more diverse, giving rise to greater demand for such machines in preproduction and replacement parts production. At the same time, changes in NC technology are expected to increase the optimum scale of operation with NC machines. Several interviewees stated that further development of computer numerical control (CNC) would permit their applications to medium-to-high volume work. Numerical control is becoming the standard ('commodity automation', as one engineer put it), and therefore cheaper. It has become just as cost effective to use numerical controls on stand-alone machine tools (e.g. lathes) as mechanical analogue controls (e.g. drums and stops). CNC increases a tool's programmability and allows several tools to be controlled from the same central computer in a flexible manufacturing system. Machining cells in which several NC tools are joined by one controller (and sometimes staffed by one or two robots) were in use at 13 per cent of plants in the automobile industry at the time of American Machinist's 1983 inventory. A logical extension is a flexible manufacturing system (FMS) which can control an entire production line, such as the one used by the John Deere Company for the machining of tractor transmission cases. However, farm tractors are much more custom-ordered than most other vehicles. None of those interviewed thought that NC machines would extensively replace conventional machines used for 'fixed' automation.

So far, numerical control has been adopted primarily to reduce labour costs and secondarily to replace expensive and inflexible automated equipment. It had been predicted in the mid-1960s that skilled workers would lose their jobs to unskilled machine tenders. Instead, there were reports of widespread shortages of skilled machinists in the mid-1970s. To these developments the automobile industry has contributed very little. Its rate of NC adoption has been modest; applications have been numerous but small. Major machining operations continue to be dominated by large-scale 'fixed' automation, which continues to use primarily unskilled labour.

(ii) Robots

Development of servo-controlled robots dates from a 1954 patent application. The first two suppliers, Unimation (now part of Westinghouse) and AMF/Versatran (later sold to Prab), made their initial sales in 1961—a total of three units. In the same year General Motors introduced its first robot to unload a die caster. Applications proceeded extremely slowly for the next 10-15 years, most robots in the automobile industry being installed one or two units at a time in existing plants. Usage was experimental, and no particular field of application dominated robotic installations. In 1969, Ford
attracted attention by converting a small number of material-handling robots for spot welding at its Kansas City assembly plant. This was the first application of robots for spot welding in North America. In the following year, General Motors successfully installed 26 robots on a respot welding line at Chevrolet body assembly plant in Lordstown, Ohio. The changes that took place since have been dramatic, both quantitatively and qualitatively. Spot welding became a primary area of robotization instead of material handling. Installations came to involve two or three dozen at a time in respect of subassembly work and over a hundred in major plan reconversions. The robot population in this industry had surpassed 1000 by 1980.

At the end of 1984, the major North American automobile producers had about 6200 robots (Table 3). About half of the total are estimated to be used for spot welding, followed by material handling, assembly and painting (Table 4). The lower figure for Ford as compared with General Motors is particularly attributable to the former's lower degree of integration (i.e. higher proportion of purchased components).

Reasons for adoption of robotic production techniques were remarkably consistent. Increased productivity and reduced (unskilled) labour costs were clearly the factors most often mentioned by the interviewees at the major assemblers. More regular quality of work, resulting in higher product quality and lower rework costs, was mentioned almost equally frequently. Greater flexibility was seldom mentioned, despite the fact that NC and robotics are especially suited to this end.

Table 3: Robots installed by the automobile producers in Canada and the United States, 1984–85

<table>
<thead>
<tr>
<th>Company</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Motors (May 1985)</td>
<td>4498</td>
</tr>
<tr>
<td>Ford (end of 1984)</td>
<td>1100</td>
</tr>
<tr>
<td>Chrysler (end of 1984)</td>
<td>618</td>
</tr>
<tr>
<td>American Motors</td>
<td>60</td>
</tr>
<tr>
<td>International Harvester (trucks only)</td>
<td>12</td>
</tr>
<tr>
<td>Volkswagen of America</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>6288</td>
</tr>
</tbody>
</table>

Notes
1. The figure for General Motors includes units on order but not yet installed.
2. Honda's and Nissan's assembly plants in the United States have been reported to use robots but their operation started after the period under study.
3. Although all companies adhere to the RIA definition of a robot, enumeration practices and dates vary across companies, so the figures and percentages given should be taken as approximations.

From individual companies. The figures for the last three firms are estimates based on press reports.
Independent parts suppliers (seven of them were interviewed) mentioned reduced labour costs as the primary motivation for robotization. The second most frequent was steadier cycle times. This is not surprising, since most uses were in material transfer and parts handling, for example in light die-casting and forging. Flexibility was mentioned in connection with NC applications but not robotics.

Three parts makers reported no use of either NC or robotics. All three manufactured highly standardized parts for which processes were almost fully automated.

With much reduced set-up times, robots and NC often permit a manufacturer to produce smaller batches almost as economically as the automatic special-purpose machines that were introduced for mass production two decades ago. Yet gains from their ‘flexibility’ usually appeared more as an afterthought than as a primary objective of their applications. Why?

First, the diversity of the products that makes their flexibility attractive is more apparent than real. There are many parts and components which are used on differently labelled makes of vehicles (e.g. Ford’s Tempo and Mercury Topaz). All three largest car makers use the same parts (e.g. power steering pumps, stamped stock tower housings) for several makes to gain economies of scale, even when the makes are physically dissimilar.

Second, those users who were motivated by flexibility had always faced situations where flexibility and short runs were desirable due to the nature of their products, for example replacement parts and power train parts for heavy trucks.

Third, some engineers—particularly those involved in flexible automation and robotization of large-scale body-assembly plants—are clearly impressed by the quick convertibility of such installations to new or revised products. One told us that flexible automation and the new forms of organization it required were the compelling necessity for the automobile industry in North
America, but he doubted that his view was widely shared in the industry. Subsequent interviews suggested that his scepticism was justified. Robotized body-assembly plants are designed for flexibility. However, they are still so new that there has been almost no experience putting one through a major model change. Flexibility may be a real pay-off but it is still in the future.

Finally, as should be clear from our discussion in Section 1, recent changes in the environment of this industry have made cost reduction and quality improvement matters of utmost urgency. In the context of the North American automobile industry, however, the contributions that greater flexibility can make to these objectives are indirect and, so far, relatively minor.

Regarding the prospects for the future, new projections of the robot population appear every year, primarily from securities and market research firms. Projections specific to the automobile industry can be found in specialized studies. Occasionally car manufacturers release their own projections. Table 5 summarizes available forecasts including a general forecast for comparison.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicasts Inc. (all manufacturing industries of the United States)</td>
<td>5093</td>
<td>30200</td>
<td>114600</td>
<td>315000</td>
</tr>
<tr>
<td>Tanner and Adolfson (the automobile industry of the United States)</td>
<td>1065</td>
<td>4700</td>
<td>10800</td>
<td>18500</td>
</tr>
<tr>
<td>Minimum effort</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate effort</td>
<td>1065</td>
<td>7500</td>
<td>16200</td>
<td>35700</td>
</tr>
<tr>
<td>Hunt and Hunt (the automobile industry of the United States)</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>15000</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>25000</td>
</tr>
<tr>
<td>General Motors (Canada and the United States)</td>
<td>302</td>
<td>5000</td>
<td>10000</td>
<td>14000</td>
</tr>
<tr>
<td>Ford Motor Company (world wide)</td>
<td>n.a.</td>
<td>3100</td>
<td>n.a.</td>
<td>7000</td>
</tr>
<tr>
<td>Ford Motor Company (Canada and the United States)</td>
<td>n.a.</td>
<td>1558</td>
<td>n.a.</td>
<td>4000</td>
</tr>
</tbody>
</table>

*Note*
The numbers of robots expected to be installed by the dates indicated. The data for General Motors are not strictly comparable with those for Ford due to e.g. the difference in their degrees of vertical integration.

From Predicasts Inc.: *Industrial Robots International*, 25 April 1983; Tanner and Adolfson (1982, Table 31); Hunt and Hunt (1983, Table 2-10); General Motors Corporation; Ford Motor Company.
Tanner and Adolfson’s study (1982) was prepared for the United States Department of Transportation. It considers four alternative scenarios (minimum effort, moderate effort, strong effort and maximum effort), based on different assumptions regarding developments in the state of the art, growth in automobile sales, tax considerations and outright government subsidies. Three years after the publication of their study, only the first two scenarios appear attainable. They are quoted in Table 5. General Motors has publicised its own installation plans and Ford has also made data available for our study. All these projections imply an annual growth rate of over 30 per cent.

3 APPLICATION OF ROBOTS IN DIFFERENT PRODUCTION PROCESSES

(i) Welding

Most body-welding work employs spot (resistance) welding guns, which can be operated by manual labour, ganged into fixed-automation welding presses or mounted at the end of a robot arm. In 1984, a fully automated body-assembly plant consisted of the following sequence of operations:

1. Component welding. Underbodies were assembled by welding presses or, less often, by robot-mounted guns. Side frames were assembled by welding robots in a laydown sideframe operation.

2. Framing and tack (spot) welding. Major components were placed and ‘toy-tabbed’ (temporarily fastened with metal tabs) manually. Precision framing was accomplished by a Fiat/Comau’s Robogate (Fiat/Comau) or similar machine and robots tack welded the parts together. Tack welding gives the body enough strength to leave the framing operation and move down the line.

3. Respot welding. Once out of the framing gate, the body started down a computer-controlled line and robots did respot welding, which is the additional spot welding intended to give the body joints the durability expected of them in an operating automobile. Since the robots spot weld much better than manual workers, there is less need to ‘overweld’ to assure structural soundness.

Robots have been introduced for body welding since 1978 almost entirely through scrapping and reequipping of existing plants, usually involving 100–150 robots per plant. Automated welding (by multispot welders and robots) accounted for about 52 per cent of all body welding in 1980 in the United States; in 1984 the percentage was closer to 65 per cent. At least one company reported over 90 per cent automation. By 1990 about all the spot-welding operations that can be automated will have been. Robots will do somewhat less of component welding than of tack and respot body
welding. Although welding presses cost about 15 per cent more than robots for underbody assembly, their hourly output is higher. At several plants body-assembly lines were automated between 1978 and 1982 but not their sideframe operations. However, at all the plants newly built or reequipped since 1982, the latter have also been automated.

Spot welding is one of the few areas where a meaningful 'degree of automation' can be computed, although even here the differences, for example in the degree of integration of welding work and in the total number of spots to be welded, make inter-plant or inter-temporal comparisons difficult. In the late 1970s, the use of welding presses allowed the automatic welding of about 60 per cent of all the spots on an automobile body in the newest plants. One engineer estimated that in 1984 fixed automation without robots would permit automatic welding of over 70 and perhaps 80 per cent of all spots.

In North America, spot-welding robots have replaced people, not automated multispot welders. The decision to use robots instead of automated multispot welding machines depends primarily on the length of the production run contemplated. Automobile underbodies may stay the same for several models through several years, and this normally tips the decision in favour of welding presses. Conversely, a line producing completed bodies must be able to switch back and forth between body types (e.g. two-door and four-door), and a robot line will be preferred in this application to the less often used welding buck, whose working configuration cannot change without extensive rebuilding. The principal motivation for robotic welding is labour savings: one robot replaces about one worker per shift, or two workers on two shifts. Tanner and Adolfson (1982) expect that a robot will help save 2.4 workers on an average, in all applications, by 1990 as experience is gained. It will probably be higher for body welding because of the reduced number of spots to be welded. However, more skilled workers are required for maintenance and programming, a matter we return to below. A secondary, but more striking, pay-off arises from the nearly perfect regularity and greater precision of work. This has resulted in major improvements in the 'fit and finish'. Tolerance had been reduced from 2.5 millimetres (manual work with conveyors) to half a millimetre in one plant we visited; discussions with engineers and a review of the literature suggest that such experience has been common. Finally, the jobs eliminated by robots have been mostly repetitive and tiring. New jobs associated with robots—skilled work in maintenance and programming—appear to be eagerly sought by those workers who can be retrained.

Arc-welding robots are less common but their application is growing. In body-assembly plants, robots are found primarily where positioning of parts is tightly controlled—installation of hinges in door frames, for example. A few applications requiring joint tracking and vision (seam following) exist, but most are still experimental. There are more numerous applications of arc-welding robots in the assembly of power-train components such as rear axles, and the greatest growth appears likely here.
(ii) Painting and finishing

Most finishing is already largely automated. Primer coating is an electrostatic dip-tank operation; much of the external finish coating can be done with fixed equipment. What remains for manual or robotic work consists of such less accessible areas as the inner surfaces of doors and wheel housings. In 1982 General Motors had only one robotic car-body painting operation. Two more were operating in early 1984 and another was expected before the end of 1985. Both Ford and Chrysler have robotic coating installations, but manual painting still remains a rule where fixed automation is not applicable. Robots are somewhat more common in component finishing, including painting of transmission cases (several manufacturers), pickup truck boxes (a Ford supplier and General Motors of Canada) and bumper coating (General Motors).¹⁹

Robots are likely gradually to replace manual workers in painting shops where fixed automation cannot be used. The need to conserve energy in drying has increased the incentive to employ some coatings whose toxicity is higher than previously used finishes. Consequently the most economical way of meeting the safety regulation is robotization of the process. The principal reason for the delay appears to be the size of the available equipment. Many applications will require retrofitting the robots into the existing small spaces. While smaller robots are becoming available, the use of robots will grow more rapidly in entirely new plants.

(iii) Casting and forging

The first robot purchased by General Motors (Unimate, 1961) was used to unload a die caster; Ford used its first robot (Versatran, 1961) in a forging plant. Despite such early start, few robots are used in the foundries of North American automobile manufacturers.

Where they are used to unload castings, robots have achieved some significant successes. One supplier saved labour by 60 per cent and reduced scrap by 5 per cent.²⁰ In most reported cases, robots handle relatively light workpieces, less than 35 kg. Where loads are heavier and the pace of work is faster, robots are too weak and too slow. The robots that load casting into transfer lines for machining can sustain the speed of the lines over 150 units per hour. However, they cannot keep up with the rate of 600 pieces per hour at which a modern foundry runs. In such cases, mechanical devices are used instead.

(iv) Material handling

Before 1970, many if not most robots were used to move workpieces along and between machining stations on transfer lines. However, the growth of spot-welding robots has reduced the relative importance of such applications,
and they are expected to account for no more than 6 per cent of total applications by 1990.21

In a growing number of plants, robots are used to tend machining stations. Most applications to date are for small to medium-sized batches. However, Ford now uses robots in high-volume transfer lines producing transmissions and transaxles.22 Further robotization of this area is somewhat constrained by robots’ load capacities and by the availability of fixed automation transfer equipment where space and output volumes permit.

One of the potential growth areas is metal stamping. The initial charging of stamping blanks into a press line is still frequently a manual operation, with the presses connected by simple pick-and-place devices. While some labour savings are expected, there is no gain in the speed of work; in this, as in many other applications, a robot will not work faster than a human. Nor is safety a significant factor, since stamping presses are equipped with two-hand starting devices. Probably less than 15 per cent of body stampings begin with robotic press insertion, though additional installations of this type are being actively considered.

Workpiece transfer and machine loading are probably the greatest potential area of application by independent parts manufacturers. In several instances, we were told that the company was studying the feasibility of robotization of a particular task. Especially in manufacturing engine parts, workers have to keep up with fixed speeds of the machines, which need to be slow enough to avoid human fatigue. Robotization of workpiece transfer, where feasible, will permit maintaining high machining speeds while allowing one worker to supervise several machines rather than load and unload one or two.

(v) Component assembly

In a 1966 survey,23 ‘automatic assembly’ occupied a minor position and received a pessimistic growth forecast. In the early 1980s much more optimistic views were expressed. But the earlier assessment appears to have been more correct so far. Of course, attempts at robotic assembly have been made. General Motors was an early developer (with Unimation) of the PUMA (Programmable Universal Machine for Assembly) and the three largest automobile companies have active programmes to find applications for lightweight assembly robots. Robotization of assembly requires discouragingly tight control of the workpiece positioning.

To solve the problem, several robot manufacturers now offer the SCARA (Selective Compliance Assembly Robot Arm). This costs about half the price of a PUMA and in several instances has made redesigning components and the assembly process for robotic insertion worthwhile. The most striking example in the automobile industry occurred in 1983, when General Motors’ Delco Electronics Division began using assembly robots and integrated circuits to manufacture car radios in the United States—an operation for-
merely performed using manual labour and transistor circuits in the Far East. The change enabled this company to bring radio production back to the United States, despite higher wages.  

24 Chrysler now uses robots to produce ignition control computers at a plant in Huntsville, Alabama. In a more recent Fisher Body (GM) application, robots are used as part of a flexible manufacturing system for the assembly of trim panels (i.e. door interiors). While robots usually require as much or more space than workers, they occupy only about half the space in this case.  

(vi) Trim, final assembly and inspection

This category contains the most diverse applications, and an enumeration is impossible. Robots are used in adhesive application and the technology here has passed beyond the experimental stage. Sealant applications have become much more numerous with the increased use of plastics in trim and finishing, and are expected to become more common, especially as vision (seam-following) systems become less costly and more flexible. For example, Chrysler uses robots to apply urethane sealant to mini-van windshields and liftgates. The result is a 50 per cent saving in labour, plus reduced waste of sealant and more consistent quality of work.  

25 Robots have been used as flexible conveying devices. For example, one car maker uses a robot to manoeuvre and position instrument panels of several different sizes and shapes without reprogramming. Trim and final assembly are receiving a great deal of attention from engineering staff. However, applications are likely to be retrofits into existing assembly lines, and spread only gradually.

The ultimate scope for robotics in final assembly is not clear. In 1982, a source associated with Ford noted that a typical Ford compact car incorporated about 17 hours of direct labour, of which no more than 5.5 were replaceable by robots.  

26 Despite this, assembly robots (both component and final) could account for as much as 30 per cent of all new installations by 1990.

Most recently constructed body-assembly plants employ some form of automated inspection of welding and body integrity. Previous methods allowed a maximum of three vehicles (and more usually one) per shift to be pulled off the line for complete inspection by eye and gauge. One automated system, using ASEA equipment, theoretically enables General Motors to inspect every car body. The major result is quality improvement—an important company goal in the light of the superior 'fit and finish' of Japanese vehicles.

Automated vehicle testing is growing rapidly. However, application of robots is confined to mechanical manipulation—for example moving the accelerator during dynamometer testing—and their potential here appears quite limited.

Table 6 shows projections on the percentage distribution of the robot population by application. The difference in the projections by General
Table 6: Percentage distribution of robots by area of application, 1981–1990

<table>
<thead>
<tr>
<th>Application</th>
<th>Actual applications</th>
<th>Projected 1985</th>
<th>Projected 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GM (May 1981)</td>
<td>Ford</td>
<td>Auto-industry (A) (1980)</td>
</tr>
<tr>
<td>Welding</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Painting</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Assembly inspection&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Machine loading&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>Parts transfer</td>
<td>8</td>
<td>5</td>
<td>12</td>
</tr>
</tbody>
</table>

<sup>a</sup>Ford data represent an early (ca. 1981) forecast, superseded by the new projection quoted in Table 5 which indicates a faster growth of robot population, but the breakdown of the new figure by application is not available.

<sup>b</sup>‘Assembly’ for the industry (A).

<sup>c</sup>‘Fabricating’ for the industry (A).

From General Motors Corporation; Ford Motor Company; Tanner and Adolfson (1982) for auto-industry (A); and Hunt and Hunt (1983) for auto-industry (B).
Microelectronics, Automation and Employment in the Automobile Industry

Motors and by Ford is striking, the latter indicating much less change over time. This seems largely due to the old date of the latter's projections. Welding clearly dominated installations in the early 1980s but its relative importance is expected to fall in the future. Painting shows fast growth in share of robots installed, but starts from a small base. Virtually all authorities consulted expected a large gain in assembly. In so far as one can see from trade journals, however, this expectation does not appear to be materializing.

4 IMPLICATIONS FOR LABOUR

(i) Employment

Public concern over the employment implications of robotics appears to have peaked in 1980–82. In the popular mind robotics have been associated with the increased unemployment in the automobile industry caused by a severe cyclical downturn and the competition from imports. One still encounters uninformed statements blaming robots for the loss of some 200,000 jobs in this industry, but they are no longer widespread. Somehow, this reminds us of our experience a quarter century ago: it was equally common, and equally wrong, to attribute the unemployment of the 1960–61 recession to the spread of fixed automation.

Table 3 puts the total number of robots at 6288. Subtracting the units on order but not installed and adding those robots owned by independent parts makers, one may estimate the total number of robots in the automobile industry of Canada and the United States at anywhere between 5000 and 7000. Assuming that each robot replaces an average of two workers, a maximum of 14,000 workers have lost their jobs to robots to date in these countries.

Regarding the future, Tanner and Adolfson (1982) and Hunt and Hunt (1983) attempt to assess the employment implications of robotization for the automobile industry.

Tanner and Adolfson estimate the labour and dollar savings with respect to their different scenarios. Their estimates for the 'moderate effort' scenario are reproduced in Table 7, since this scenario appears the closest to the reality as confirmed by data published subsequently. By 1990 they predict a loss of 73,200 unskilled jobs, a gain of 6200 skilled jobs and a net loss of 67,000 jobs. The 'moderate effort' scenario assumes 'some recovery of the domestic automobile market and a modest decline in interest rates, making more capital available for productivity improvements'. The study does not consider the possibility that a stronger recovery of the automobile industry could lead to a lesser decline in employment, for example as older, less automated plants are kept in service longer. This appears to be exactly what happened in 1983–84, when the employment increased in this industry (Table 1). No explanation is offered regarding the labour replacement ratio. The average of two workers per robot on two shifts is, however, a commonly accepted rule of
Table 7: Estimated labour-saving effect of robotization (Tanner and Adolfson's 'moderate effort' scenario)

<table>
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</thead>
<tbody>
<tr>
<td><strong>Direct labour savings per robot per shift</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worker Dollars</td>
<td>34 700</td>
<td>34 700</td>
<td>38 600</td>
<td>42 400</td>
<td>46 300</td>
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<tr>
<td>Robot utilization&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2-shift (%)</td>
<td>70</td>
<td>55</td>
<td>45</td>
<td>35</td>
<td>30</td>
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<tr>
<td>3-shift (%)</td>
<td>30</td>
<td>45</td>
<td>55</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>'Other savings' factor ($)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7 000</td>
<td>8 000</td>
<td>10 000</td>
<td>12 000</td>
<td>13 000</td>
</tr>
<tr>
<td><strong>Average annual savings per robot</strong></td>
<td>86.8</td>
<td>93.0</td>
<td>108.4</td>
<td>124.3</td>
<td>138.0</td>
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<td><strong>No. of robots</strong></td>
<td>1 065</td>
<td>4 065</td>
<td>7 500</td>
<td>16 200</td>
<td>22 600</td>
</tr>
<tr>
<td><strong>Direct labour loss</strong></td>
<td>2 200</td>
<td>8 900</td>
<td>19 100</td>
<td>47 200</td>
<td>73 200</td>
</tr>
<tr>
<td>Skilled trade gain&lt;sup&gt;d&lt;/sup&gt;</td>
<td>250</td>
<td>1 000</td>
<td>2 000</td>
<td>4 200</td>
<td>6 200</td>
</tr>
<tr>
<td><strong>Net loss</strong></td>
<td>1 950</td>
<td>7 900</td>
<td>17 100</td>
<td>43 000</td>
<td>67 000</td>
</tr>
</tbody>
</table>

<sup>a</sup>Assumes increasing efficiency of robots through technological improvements, sensory feedback, etc.

<sup>b</sup>Spot welding, arc welding and painting are associated with car-assembly operations which operate on two shifts a day; other applications are associated with basic manufacturing operations which operate on three shifts a day. The change in shift utilization reflects the change in applications.

<sup>c</sup>Energy and material (painting); higher output, reduced scrap and rework (fabrication and manufacturing)—factor varies with percentage of utilization of robots for these operations.

<sup>d</sup>Based on one skilled tradesperson per ten robots per operating shift.

From Tanner and Adolfson (1982, Tables 31 and 36). Footnotes in original.

The authors assume some progress in the robot's efficiency and reliability over time. They also assume one skilled maintenance person per ten robots. This estimate of 'skilled trade gain' is at the lowest end of the estimates we obtained in the course of our research. An engineer at one car company estimated that one skilled maintenance worker would be needed for every six robots. Hunt and Hunt (1983) compute labour displacement on a crude one-robot-equals-two-workers ratio, but disaggregate by type of application. They begin their exercise by identifying each robot with an occupation as tabulated in the Bureau of Labor Statistics Industry-Occupation Employment Matrix. Each robot expected to be installed by 1990 is assumed to replace two workers on average. By multiplying the number of robots identified with respect to each occupation by two, the number of workers replaced by robots was obtained. Columns (2) and (3) in Table 8 give these replacement figures as percentages of the total number of workers in the different occupational groups in 1980, which are given in column (1). 'Low' and 'high' figures correspond to the 'low' and 'high' robot population figures given in Table 5.
Table 8: Employment impact of robots in the United States automobile industry, 1980–1990

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding</td>
<td>41 159</td>
<td>15 20</td>
<td>3 15</td>
</tr>
<tr>
<td>Assembly</td>
<td>175 922</td>
<td>5 10</td>
<td>14 25</td>
</tr>
<tr>
<td>Painting</td>
<td>13 556</td>
<td>27 37</td>
<td>-8 -2</td>
</tr>
<tr>
<td>Machine loading/unloading</td>
<td>80 725</td>
<td>12 20</td>
<td>6 15</td>
</tr>
<tr>
<td>All operatives and labourers</td>
<td>467 846</td>
<td>6 11</td>
<td>12 24</td>
</tr>
<tr>
<td>All employment</td>
<td>773 797</td>
<td>4 6</td>
<td>15 29</td>
</tr>
</tbody>
</table>

From Hunt and Hunt (1983, Tables 3.3, 3.8, 3.9).

above. The authors then set this against the BLS employment projections for 1990, which are based on the assumption that robots would have a negligible employment effect. Following the philosophy of the acceleration principle of investment, the low (high) robot population is associated with the low (high) demand growth variants of the BLS occupational employment projections. By subtracting the low (high) robot growth displacement figures from the BLS low (high) employment growth projections, the net employment changes between 1980 and 1990 were calculated. As shown in Columns (4) and (5), Table 8, the job displacement was estimated to more than offset the BLS projection of employment growth only in the case of painters.

In the meantime, at the level of individual firms, there can be cases of actual replacement of workers by robots. Even in such cases, however, normal attrition could conceivably handle much of this job loss. For example, assuming the labour replacement ratio of two workers per robot, the 14 000 robots General Motors expects to install in North America by 1990 will eliminate 28 000 jobs. However, Krause (1984) reports that GM's expected attrition through 1990 will average 4.1 per cent a year, or 97 000 workers by the end of the decade. Moreover, a position paper prepared by General Motors in connection with the 1984 contract negotiations suggests that the corporation will try to eliminate 60 000–120 000 positions by August 1986, 'apparently through measures such as automation, work-rule changes, attrition, and plant closings'. Even if only half the affected workers are hourly employees, there is no way in which robots could account for more than about a quarter of the total. Set against the massive forces affecting the automobile
industry in the 1980s and their employment implications, the effect of robotization is small. Moreover, even greater numbers of jobs would be lost because of increased imports of vehicles and parts from abroad if robotization did not take place.

(ii) Industrial relations

As noted in Section 1, flexible automation is taking place in a peaceful collective bargaining environment. Both the United Auto Workers and the companies expect employment losses, at least for unskilled workers. These are occurring in the following context:

1. The union has for many years accepted technological change in principle and has not resisted robotization, basing its improvement-factor demands on expected productivity increase.33
2. The union has, however, resisted the loss of its members' jobs to other workers. All collective agreements since 1967 have provided, in one form or another, that machines which replace workers be tended by union members from within the same bargaining unit.
3. Especially after the 1982 collective bargaining contracts, the rigidity of conventional job classifications and work assignments among skilled workers began to disappear.34 In fact, under the GM/UAW 'pay for knowledge' training programme, workers have an incentive to acquire more than one skill, as robot maintenance often requires more than a single skill.
4. Job security has long been a goal of the union, but this goal is to be attained by measures other than halting automation.
5. Virtually every major installation of automated equipment since 1980 has taken place in an atmosphere of relatively open communication between workers and management, with the union taking a clearly defined and accepted role as spokesman for the hourly employees. In other words, there have been few reports of management using communications with workers as a means to circumvent the union.

Bargaining has created mechanisms which can deal at least partly with unemployment caused by automation. Supplemental Unemployment Benefits (SUB) funded by the companies since 1955 and the state unemployment insurance scheme can temporarily compensate for up to about 90 per cent of the lost earnings, although SUB funds can be, and sometimes have been, exhausted when unemployment becomes severe and prolonged. Early retirement schemes have been available since 1971 for workers with 30 years' seniority. Proposals to increase their attractiveness and encourage older workers to retire early are commonly made by local UAW officers. Thus, the main losers from automation in the automobile industry are likely to be the new entrants to the labour force, for whom job openings will be considerably fewer.
Retraining and retention

A number of local agreements in 1979 dealt with retraining issues related to robot programming and servicing. All the major companies now offer their skilled workers courses in electronics and programming. In some plants where the number of certified skilled workers (e.g. electricians, pipefitters, millwrights) is inadequate, apprenticeship programmes have been reactivated or newly introduced to provide the basic prerobotic skills. These workers must be certified through the Skilled Trades Department of the UAW, which negotiates their training and employment with the companies, participating educational institutions and state authorities. Different institutions and media are used. For example, Ford's Robotics and Automation Applications Consulting Center operates classes on robotic technology attended by mixed groups of hourly workers, managers and engineers. The courses organized by the companies appear to be well received; the hourly technicians found their jobs more attractive and secure than their former work (in some cases, skilled trades). Company management is extremely pleased with the trainees' eagerness to learn and with the capabilities of their hourly people in handling the new technologies once the retraining is under way or completed.

In fact, management has little choice. Both the companies and the union are committed to recruiting enough skilled robotics technicians from among the existing employees. Whether this will provide enough people with the requisite skills is open to question. Tanner and Adolfson (1982) flatly state that it will not. Should it be necessary to resort to external recruiting, a growing pool of robotics technicians graduating from community (i.e. two-year) colleges can be tapped. However, this is clearly a last resort which both the companies and the union want to avoid. A potentially more serious problem concerns the availability of applications engineers. To date, the engineering colleges have been unable to supply enough of these people, for whom employment opportunities extend far beyond the automobile manufacturers and suppliers.

As troublesome as finding the sufficient number of skilled robotics technicians is the problem of craft barriers to work assignments. Workers are certified into skilled trades and an assignment requiring a specific skill must be given to a worker with the necessary certification. This rigidity has been accepted for nearly two decades, occasionally causing minor irritations. The diffusion of robots has, however, increased the problem because servicing them may demand several certified skills in addition to the robotics knowledge. For example, maintenance of a hydraulically operated robot requires the combined services of a pipefitter, an electrician and (if the robot needs to be removed from the line) a millwright. Since one needs a complete basic training in each skill to obtain a certificate, technicians who combine the right amount of all three skills are unlikely to be produced. What is really needed is not so much a formally certified 'robotics technician' as someone with the basic knowledge in a number of fields. To meet this requirement, companies have been trying to reduce the number of formal skill classifications in the last
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few years. The 1984 settlement of General Motors and Ford with the UAW provided for some reductions. The 1985 negotiations between General Motors and the UAW related to the Saturn project and the joint venture with Toyota resulted in dramatic reductions. Chrysler requested similar reductions in its 1985 contract negotiations with the UAW.

Unemployment and income security

For many workers who lose their work a new job must be sought outside the industry. One result of the 1982 collective agreements was the establishment of retraining programmes funded by the companies and operated jointly by them and the United Auto Workers. For the first time the companies had to agree to offer retraining to workers certified to be permanently unemployed (as opposed to temporarily laid off). At the time of writing (spring 1985), the greatest efforts were under way in Detroit, Flint and California. But they are related more to permanent closures of plants than to automation. At General Motors' Oldsmobile Division and related Fisher Body plants, such programmes have been introduced not so much because over 150 robots are going to be installed as because the smaller cars the facilities are expected to produce require less labour. Redundant workers have been trained as 'appliance repairmen, dental assistants, licensed practical nurses, word processors, waste-water technicians, and cable television installers'. It is too early to make a judgement on the result of these programmes. Any evaluation must be tempered by the fact that the early graduates from this training had to look for work in the most severe recession since the Second World War. Still, thousands of workers have already found jobs during or after these programmes, including 3300 former employees of General Motors in California.

One innovation of the 1982 contracts was a Guaranteed Income Stream (GIS) programme. This grants to high-seniority workers who have been laid off payments of 75 per cent of lost earnings, until retirement if necessary. However, GIS participants must accept any bona fide job offer, either inside or outside the automobile industry. Otherwise they will lose their GIS payments.

At some plants, 'lifetime employment' programmes have been instituted on an experimental basis. In exchange for substantial concessions from the local union, the company guarantees lifetime employment to 80 per cent of the plant's workers. So far, the experiment has had little appeal to local officers and workers; the combination of a continued 20 per cent risk of unemployment and the concessions are considered to be too high a price. Moreover, car sales in 1984 were from 10 to 30 per cent above the 1983 level, workers were called back, and for those with jobs the threat of unemployment appeared more remote than it was when the last collective agreement was negotiated.

In the 1984–85 negotiations the union's demands about job security included a drastic reduction in mandatory overtime. The companies have a substantial incentive to increase production by overtime work, without calling
back laid-off workers or starting another shift. Even with overtime premium payments, they can save substantial costs. The union’s concern was that this would reduce the number of workers employed. This was the only job-security issue consistently mentioned in the press before the 1984–85 negotiations got under way. However, the settlement emphasized employment and/or income guarantees for senior employees.

Few of the agreements and programmes emerging from recent collective bargaining that have been discussed above relate specifically to robots or other forms of automation. They were the expected results of a prolonged and severe recession in the automobile industry that had several concurrent causes. Indeed, without the elements of retraining programmes related to robotization, our discussion in this section could have been written almost identically in a setting where manufacturing technology was static and robots did not exist. Job- and income-security institutions have been designed to deal with problems of unemployment from any cause; there is no ‘specific emphasis on robots as such’.

5 SUMMARY AND CONCLUSIONS

Adoption of numerical control technology by the automobile industry of North America has been gradual. Applications have been predominantly low-to-medium volume machining operations. Really large applications, with high output rates, are becoming significant only with the development of computer numerical control. Fixed automation still dominates machining wherever possible.

Robotic applications spread slowly for a decade and a half after 1965. They have grown at an annual rate exceeding 30 per cent since 1980. Current applications are dominated by spot welding, where multiple-robot installations are feasible and can add up to 150 robots at a time in a new or substantially rebuilt body-assembly plant. By 1990, welding presses and robots will account for over 90 per cent of spot welding and new robotic applications will be found in painting and assembly.

The major attraction of robots for car producers clearly lies in the labour savings, expected to be 363 (US 1980) dollars per car by 1990. High regularity in quality of work and cycle time is an important secondary effect.

Labour savings may result in job losses of up to 15 per cent by 1990 as compared with the 1980 level, assuming the constant 1980 production level. However, these losses have not been directly opposed by the union representing the majority of the industry’s workers. In principle, the United Auto Workers views any automation-caused job loss as the price of higher productivity and higher real wages. In practice, resistance to technological change has appeared counterproductive, since North American users faced with higher prices of domestically produced vehicles may buy foreign cars and leave even fewer jobs. The union’s role has been largely to make sure that its members continue to hold the remaining jobs, to appropriate some of the
productivity gains and to benefit from various job- and income-security measures, leaving the companies relatively free to continue introducing new technologies. Where automation has caused a redundancy of workers, income-security programmes appear adequate to alleviate a substantial portion of the human costs.

Robots and NC represent, in the words of Hunt and Hunt (1983, p. 166), only one small step in a continuous technological evolution in the automobile industry. Furthermore, technological change is only one of the forces likely to affect this industry in the remainder of this century. How adaptable management, labour and the bargaining institutions are in confronting such change remains to be seen. More depends on macro-economic and labour-market policies than on what happens in a single industry—even one as important as automobile manufacturing.

NOTES

1 Fieldwork for this study was carried out in the second half of 1983. A set of questions was sent to the four largest automobile assemblers (General Motors, Ford, Chrysler and American Motors) and about 20 parts suppliers. The questions, dealing with the motivations for and results of adopting (or not adopting) flexible automation methods, were tailored to the companies' known characteristics and product mixes. This was followed up by interviews with manufacturing executives and plant and laboratory visits. Information secured in interviews generally came with the understanding that company identities would remain confidential. Companies and company-specific applications are shown only if the information has appeared in published form.

2 See White (1971; 1982).


6 The Hirfindahl index is the sum of the squares of the shares of each model. It has a long history as a measure of market concentration, and it is also employed as a measure of output diversification by multi-product firms (see Adelman, 1969). We truncate it arbitrarily at the ten largest observations, since its size is unaffected by very small shares.

The data are from Ward's Automotive Yearbook: 1982. Most tabulations of makes and models are somewhat arbitrary. For example, the Ward's data usually lump all the larger models (usually body-on-frame, rear-wheel drive) of a division (e.g. Chevrolet) into one classification. Such models may be assembled together, but may incorporate a greater diversity of components. Conversely, the data list as separate models an entire line such as GM's J-cars (one for each of GM's five divisions) or Chrysler's K-body line (one each for Plymouth and Dodge). The data exclude vans used as passenger vehicles; how the 1984 and 1985 mini-vans will be treated is not known at the time of writing.

7 For a detailed example of the 'just-in-time system' at a totally rebuilt Chrysler plant in Windsor, Ontario, see Mathis (1984, pp. 5–7).
Company annual reports often tell the percentage of sales that is paid to suppliers. For General Motors this percentage rose from 46.8 per cent in 1967 to 53 per cent in 1978. It fell negligibly from 61.3 per cent to 61.0 per cent for Ford and from 69.7 per cent to 66.8 per cent for Chrysler. These figures, however, relate to world operations, not just those in North America, and they are not available for all years. Moreover, they are affected by non-automotive businesses in which each company is engaged. General Motors' automobile business accounted for 87 per cent of total North American sales in 1970 and 93 per cent in 1979, and probably 90–95 per cent since 1980. Ford's automobile business has accounted for 90–94 per cent of its North American revenues since 1970. Chrysler's automobile operations accounted for almost 100 per cent of its sales in 1983. From 1977 to 1981, this fraction varied between 92 and 96 per cent. Comparable figures for American Motors are not available.

The terms negotiated between Ford and the UAW are typical, and have been chronicled through 1979 by the United States Bureau of Labor Statistics. See the Bureau's Wage Chronology: Ford Motor Company and United Automobile Workers (1973 and 1979).

Business Week, 4 March 1972, p. 69. See also Woodcock (1974).

Address of Alfred S. Warren, Jr, Vice-President/Industrial Relations, General Motors Corporation, to Michigan State University Annual Management Conference, 28 October 1981. See also Business Week, 17 September 1979, p. 120.


One engineer estimated that over 50 per cent of all sheet-metal dies were produced by NC machines.


Tanner (1982). According to the definition by the Robotic Industries Association (RIA), a robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or other specialized devices through variable programed tasks for the performance of a variety of tasks.

For one sampling, see Hunt and Hunt (1983), Chapter 2. One extensive and detailed forecast was published by Smith and Wilson (1982) for the Society of Manufacturing Engineers. Two securities analysts with extensive knowledge of the robotics industry and robot markets are Paul Aron (Daiwa Securities) and Laura Conigliaro (Prudential-Bache Securities). Both are popular speakers at robotics conferences; see, for example, Conigliaro (1984).


American Machinist, June 1978, p. 85; Robotics Today '82 Annual, pp. 207–211.


Automation News, 4 June 1984, pp. 9 and 23.


See, for example, State Journal (Lansing, MI), 10 June 1985, p. 1A.


A Ford source offers a similar comparison: assuming Ford has 4000 robots by 1990, as planned (Table 5), and a static level of automobile production, about 8000 workers could be displaced. Compared with Ford's normal workforce and turnover, the loss is quite small.
32 Wall Street Journal, 21 February 1984, p. 2. For an update in connection with the 1984 contract negotiations, see the same publication, 9 September 1984, p. 2. Business Week had earlier predicted a substantial permanent job loss for the industry from its 1980 levels (see ‘Detroit’s jobs that will never come back’, 23 May 1983, p. 168).

33 Weekly (1982).

34 In connection with the contract negotiations in September 1984, a UAW official remarked to the press that if workers received an acceptable degree of overall job security (the union’s top priority), the value of craft-protecting barriers would be considerably less (Wall Street Journal, 12 September 1984, p. 2).

35 This paragraph is based on materials furnished by the General Motors Department of the United Auto Workers, in particular, UAW-GM Informational Subcouncils (1981), which is intended for guidance of local union officers. It includes several detailed local union examples of robot-programming assignments.

36 Business Week, 9 January 1984, p. 91. This article presents a compact and useful discussion on the subject matter dealt with in this section, primarily on the basis of published and unpublished materials furnished by the Research Department of the United Auto Workers.

37 See Weekly (1982).

38 Tanner and Adolfson (1982).

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poration', Paper presented by Car and Truck Assembly Operations, Chrysler Corporation, at University of Michigan Management Briefing Conference on Robotics, Traverse City (MI), August 9.


Ward's Automotive Yearbook (Detroit), various issues.


CHAPTER V

Microelectronics and Rationalization of the French Automobile Industry

Susumu Watanabe

Since the late 1970s, the French automobile industry has been in trouble. Production, exports and employment have decreased while imports increased. The Government has been assisting the industry with modernization programmes built around microelectronic production technology and with policy schemes for workers who lose their jobs. A recent report of the Commission Nationale de l'Industrie (Dalle Report) urges the industry to reduce overmanning, while the media frequently report job losses 'caused by the new technology'. On the basis of a review of scattered items published and of first-hand information obtained from visits to the two major automobile company groups of the country, the present chapter attempts to assess the role of the new technology in the rationalization programme of this industry and its employment impact. After a review of its structure and trends (Section 1), we will examine the extent and pattern of diffusion of microelectronic machinery (industrial robots in particular) (Section 2), the technical, economic and socio-organizational constraints on its diffusion (Section 3) and the impact on employment, skill requirements and work organization (Section 4). Section 5 discusses government programmes which are particularly relevant to the automobile industry. The final action summarizes our main findings.

1 TRENDS AND STRUCTURE OF THE INDUSTRY

(i) Production, employment and investment

Production of automobiles (cars, buses and trucks) continued to grow rapidly until 1973, when 3.6 million units were produced as compared with 1.5 million in 1965. Exports contributed to this growth more than home demand. Employment expanded, more or less following the cyclical pattern of production. Both recovered quickly from the first oil shock of 1973–74 and continued to expand until the peak in 1978–79. The decline in production after 1979 was due to a rapid increase in imports and stagnant exports and
home demand. This suggests a loss of international competitiveness of the French industry. The number of vehicles produced per worker fluctuated with the production and employment levels until 1981. After that, it increased sharply as employment continued to decline (Table 1).

In so far as the automobile assembly sector of the industry is concerned, investment has continued to grow consistently since 1974. In real terms, however, it has been falling since the beginning of the present decade (Table 2). From the investment-value added ratio given in the table, one may suspect a decline in the rate of investment after the oil crisis, which has been a common phenomenon among French industries. The Dalle Report expresses concern about the low rates of investment by Renault and Peugeot (PSA) Groups. Between 1979 and 1983, they invested 5.1–8.3 per cent and 8.0–4.3 per cent of their annual turnover, respectively. In contrast, Volkswagen invested 10–13 per cent during the same period, and General Motors 10–15.5 per cent in 1980–82 (8.1 per cent in 1979 and 5.4 per cent in 1983). The relatively low rate of investment by the French firms, especially after 1980, may be attributable partly to their business losses since the end of the 1970s.

The production and employment trends of the industry given in Table 1 mask differences in the conditions at the two assembler groups. After 1975 production at Renault continued to increase to its record level of nearly 1.9 million units in 1983 with minor fluctuations, although it fell to 1.6 million in the following year. Its workforce reached a peak (142 979) in 1976, and thereafter has continued to decline very gradually but steadily. Consequently, output per worker has continued to rise although it fluctuated somewhat with the overall output level. In contrast, at PSA production reached its record level (2.1 million) in 1978, and thereafter continued to fall to 1.4 million in 1984 with a marginal recovery in 1983. Its workforce also decreased quickly from 160 110 in 1978 to 110 000 in 1984. This was, however, not enough to raise output per worker (Table 3). These contrasting trends of the two groups seem to be explained largely by the difference in their investment strategies. Renault has expanded by building new plants (e.g. at Douai) and renovating older plants. In contrast, Peugeot acquired existing firms (Citroën and Talbot). The latter group needed organizational rationalization before regaining its competitive position.

The Dalle Report argues that, in order to recover its international competitiveness, this industry needs to cut its labour force by 74 000 between 1984 and the end of 1988: 54 000 at the assemblers and 20 000 among the component manufacturers. The majority of industrialists appear to agree with this recommendation. As a matter of fact, the assemblers had already begun their efforts to reduce surplus labour towards the end of the 1970s, and in June 1985 Régie Renault (excluding Renault Véhicules Industriels) confirmed a plan to cut the number of its employees from 98 000 in 1984 to 77 000 by the end of 1986.

An important aspect of the French automobile industry is the high propor-
Table 1: Trends in the French automobile industry (in '000 vehicles and workers except (7))

<table>
<thead>
<tr>
<th>Year</th>
<th>Production&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Exports&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Imports</th>
<th>Employment&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Output per worker (1)/(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
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<td>1965</td>
<td>1526.4</td>
<td>521.4</td>
<td>159.1</td>
<td>270.9</td>
<td>170.4</td>
</tr>
<tr>
<td>1970</td>
<td>2503.7</td>
<td>1277.9</td>
<td>327.2</td>
<td>386.5</td>
<td>252.9&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1971</td>
<td>2747.4</td>
<td>1315.8</td>
<td>396.2</td>
<td>397.0</td>
<td>257.4</td>
</tr>
<tr>
<td>1972</td>
<td>3017.5</td>
<td>1458.0</td>
<td>459.7</td>
<td>387.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>265.4</td>
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<td>1973</td>
<td>3217.8</td>
<td>1552.9</td>
<td>510.9</td>
<td>402.6</td>
<td>273.7</td>
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<td>1974</td>
<td>3075.1</td>
<td>1560.0</td>
<td>430.1</td>
<td>385.4</td>
<td>262.0</td>
</tr>
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<td>1975</td>
<td>2861.3</td>
<td>1499.9</td>
<td>440.0</td>
<td>385.0</td>
<td>265.1</td>
</tr>
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<td>1976</td>
<td>3402.7</td>
<td>1647.5</td>
<td>695.9</td>
<td>405.3</td>
<td>276.5</td>
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<td>1977</td>
<td>3507.9</td>
<td>1769.5</td>
<td>670.7</td>
<td>407.4</td>
<td>278.1</td>
</tr>
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<td>1978</td>
<td>3507.9</td>
<td>1732.7</td>
<td>648.4</td>
<td>412.6</td>
<td>281.0</td>
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<td>1979</td>
<td>3613.5</td>
<td>1859.9</td>
<td>712.4</td>
<td>410.5</td>
<td>269.2</td>
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<td>1980</td>
<td>3378.4</td>
<td>1707.8</td>
<td>790.1</td>
<td>385.5</td>
<td>253.7</td>
</tr>
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<td>1981</td>
<td>3019.4</td>
<td>1550.8</td>
<td>902.3</td>
<td>362.9</td>
<td>239.7</td>
</tr>
<tr>
<td>1982</td>
<td>3148.8</td>
<td>1603.4</td>
<td>1118.8</td>
<td>360.6</td>
<td>238.1</td>
</tr>
<tr>
<td>1983</td>
<td>3335.9</td>
<td>1756.5</td>
<td>1107.1</td>
<td>352.1</td>
<td>233.0</td>
</tr>
<tr>
<td>1984</td>
<td>3062.2</td>
<td>1676.5</td>
<td>1030.1</td>
<td>329.5</td>
<td>215.3</td>
</tr>
</tbody>
</table>

<sup>a</sup>The figures include vehicles exported in completely knocked-down form (CKD), but not parts and components exported individually.

<sup>b</sup>The figures in (6) are based on the statistics published by the Fédération des Industries des Equipeements pour Véhicules (FIEV), which are 70 000-80 000 short of the corresponding figures published by the Union des Industries Métallurgiques et Minières (UIMM). The latter are based on the census of establishments.

<sup>c</sup>A new series of data.

From Chambre Syndicale des Constructeurs d'Automobiles (CSCA).
### Table 2: Investment in French automobile assembly (million francs)

<table>
<thead>
<tr>
<th>Year</th>
<th>Investment In current prices (1)</th>
<th>Investment In 1974 prices (2)</th>
<th>Percentage of value added (3)</th>
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<tbody>
<tr>
<td>1974</td>
<td>5 048</td>
<td>5048</td>
<td>20.7</td>
</tr>
<tr>
<td>1975</td>
<td>5 106</td>
<td>5414</td>
<td>16.4</td>
</tr>
<tr>
<td>1976</td>
<td>5 706</td>
<td>5634</td>
<td>12.7</td>
</tr>
<tr>
<td>1977</td>
<td>7 391</td>
<td>6912</td>
<td>14.6</td>
</tr>
<tr>
<td>1978</td>
<td>8 723</td>
<td>7822</td>
<td>15.5</td>
</tr>
<tr>
<td>1979</td>
<td>9 149</td>
<td>7238</td>
<td>14.0</td>
</tr>
<tr>
<td>1980</td>
<td>11 464</td>
<td>8337</td>
<td>16.1</td>
</tr>
<tr>
<td>1981</td>
<td>12 391</td>
<td>8119</td>
<td>16.7</td>
</tr>
<tr>
<td>1982</td>
<td>13 389</td>
<td>7899</td>
<td>15.7</td>
</tr>
<tr>
<td>1983</td>
<td>13 112</td>
<td>6963</td>
<td>13.7</td>
</tr>
<tr>
<td>1984</td>
<td>14 132</td>
<td>6625</td>
<td>14.1</td>
</tr>
</tbody>
</table>

From CSCA for (1) and (3). For (2) the amounts have been calculated using the index of wholesale prices for industrial products published in INSEE: *Annuaire Statistique de la France*, 1984, and *Bulletin Mensuel de Statistique*, Oct. 1985.

### Table 3: Production and employment in Renault and Peugeot Groups

<table>
<thead>
<tr>
<th>Year</th>
<th>Renault Group</th>
<th>Peugeot Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Production ('000 vehicles) (A)</td>
<td>Employment ('000 workers) (B)</td>
</tr>
<tr>
<td>1978</td>
<td>1422</td>
<td>138</td>
</tr>
<tr>
<td>1979</td>
<td>1592</td>
<td>136</td>
</tr>
<tr>
<td>1980</td>
<td>1713</td>
<td>135</td>
</tr>
<tr>
<td>1981</td>
<td>1527</td>
<td>132</td>
</tr>
<tr>
<td>1982</td>
<td>1720</td>
<td>131</td>
</tr>
<tr>
<td>1983</td>
<td>1880</td>
<td>129</td>
</tr>
<tr>
<td>1984</td>
<td>1645</td>
<td>123</td>
</tr>
</tbody>
</table>

From CSCA.
tion of immigrant workers. In mid-1985, they accounted for 25 per cent of the assemblers' employees. Their proportion varied from plant to plant: 46 per cent of employees at Flins, 58 per cent at Billancourt and 77 per cent of production workers at Aulnay. The proportion is particularly high in the Parisian region. Even at Mulhouse, Alsace, however, 70 per cent of the unskilled production workers were immigrants at Peugeot's body-assembly plant when we visited it in June 1985. Together with older workers involved in the early retirement programmes, such workers have been among the most vulnerable to dismissal, as will be discussed below.

(ii) The Structure of the industry

The assembly sector of the French automobile industry virtually consists of two groups, Renault and Peugeot SA (PSA). The Régie Nationale des Usines Renault (RNUR) has been nationalized since 1945. Since 1984 Renault has included Matra, which was formerly part of Talbot. The automobile division accounts for about 85 per cent of the group's turnover: 70 per cent in the passenger car production and 15 per cent in heavy truck production by Renault Véhicules Industriels (RVI), which consists of the former Berliet and Saviem. PSA has two major automobile-producing companies, Peugeot, including Talbot which was acquired in 1978, and Citroën, which was bought in 1974. The automobile division contributes over 90 per cent of the Group's turnover. The two groups share a number of component manufacturers such as La Française de Mécanique (motor production), la Société de Transmissions Automatiques, la Société de Fonderie et de Mécanique de l'Est, la Société des Usines Chausson. They also collaborate in certain domains of research. Apart from these two groups, there are three producers of commercial vehicles: CBM, Sovam and Unic. The combined output of these three firms was only 3769 units in 1984.

The French assemblers spend over 50 per cent of their turnover on materials, of which more than a half consists of parts and components. Less than 10 per cent of the parts and components are imported. The Fédération des Industries des Equipements pour Véhicules (FIEV) has 350 members, who employed a total of 125 000 workers in 1984. Of this total, 29 firms employed over 1000 people, 112 firms 100-1000, and 209 firms 10-100. Half of the total labour force cited above was employed by 22 firms, including affiliates of Renault and PSA.

Component manufacturers are considered to be, generally speaking, too small to compete internationally, partly because of their poor financial position. They have been suffering from declining demand, increasing prices of raw materials and low prices paid for their work, which in turn can be attributed both to governmental control over the vehicle prices and to the assemblers' severe purchasing policy. The poor financial position of the component manufacturers reduces their investment capacity either by borrowing or by self-financing.
The relationship between the assemblers and component manufacturers is unstable, orders being offered on an *ad hoc* basis and at short notice. Efforts to develop partnership have, however, been started. In 1980, four commissions composed of the assemblers and component makers were created to examine the problems of quality, productivity, inventory organization and management, and standardization. In 1984, le Groupe pour l'Amélioration des Liaisons dans l'Industrie Automobile (GALIA) was created to promote the computerization of transactions between the assemblers and their component manufacturers. A new commission on the terminology of information technology in commercial and industrial businesses was set up as part of this programme.

Renault recently announced a new policy whereby long-term contracts for three to five years would be offered to component suppliers who passed a certain standard with respect to creativeness, service, quality of work, competitiveness, financial capacity and managerial staff. It is believed that, when applied, the new policy will halve the number of suppliers (1800 in mid-1985) through its stringent selection criteria. Payment in 90 days after the delivery is likely to become a general rule.

Over 1000 small firms work as subcontractors to the assemblers and component makers; the average size of mechanical parts producers is 50–60 workers. Approximately 10 per cent of the assemblers' total purchases are direct from such producers. In the same way as component suppliers, subcontractors have been suffering from both a decline in demand and low prices paid for their work, regardless of the size of their enterprise. Small machining shops and plastic moulding shops have been particularly hard hit.

Moreover, the amount of subcontracted work has been decreasing, at a rate of 3–4 per cent a year, because of the rationalization of vehicle design and consequent reduction in the number of small parts. It has been reported that both assemblers and major component producers are trying to reduce the number of subcontractors.

## 2 DIFFUSION OF MICROELECTRONIC TECHNOLOGY

To regain their competitiveness, the French assemblers have been endeavouring to modernize their plants, improve management techniques and increase productivity. In order to utilize their production facilities more efficiently, they began to adopt new ideas and techniques, some of which are directly copied from the Japanese experience (reduction in the time required for tool change, elimination of breakdown of equipment, rejected products and other wastes, QC circles).

According to the Association Française de Robotique Industrielle (AFRI), the robot population in French industry grew from only 30 in 1974 to 580 in 1980, 790 in 1981, 1384 in 1982, 1920 in 1983 and 2750 in 1984. The Association expects installation of an additional 1200 robots in 1985 to raise the total population to 3950. The automobile industry had 797 robots, or 29
per cent of the national total, in 1984. It was the largest user, followed by the mechanical industry which had 687 robots. However, its relative importance as the user of robots has been decreasing rapidly: it had 40 per cent of the national total in 1982 (560 units) and 36 per cent in 1983 (690 units).

The AFRI data cited above are in broad agreement with the information obtained in our fieldwork. In May 1985, there were 108 robots in Flins and 125 in Douai, and 450–500 in the Renault group as a whole. About 80 per cent were used for welding, 15 per cent for material handling and 5 per cent for painting. PSA had 323 robots of the playback and more sophisticated categories in February 1984: 214 (65 per cent) for spot welding, 32 (10 per cent) for arc welding, 26 (8.0 per cent) for material handling in foundry and forgery, 21 (6.5 per cent) for sealing, 20 for charging and discharging machine tools and ten for assembly and testing. The closeness of the figures given by the assemblers to the AFRI data may be interpreted as a sign of a very limited use of robots by component manufacturers. (The total number of robots installed by PSA rose to 600 by the end of 1985.)

According to the information we obtained during our visits, the primary motivations for robotization at Renault were flexibility in welding, work environment/safety and health in painting and labour saving and work environment in material handling. At Peugeot, flexibility and quality control were the main objectives of robotization, although work environment/safety and health was an important consideration in painting shops and foundries. It was, however, noted that the primary motivation for robotization had changed over time. When the first robots were introduced in 1973 in painting shops, improvement of work conditions was the main objective and increased flexibility and improved quality control were welcome side effects. The same was the case with the robotization of welding processes during its initial period. In 1985, in contrast, quality of work and flexibility (i.e. capacity for quick adaptation to users’ needs) were the primary motivating factors.

Such shifts in the motivation for robotization were explained by a number of factors: the two oil crises and higher oil prices, the international economic recession, the emergence of the Japanese firms in the international market, and a shift in the Western automobile market from growth to replacement. All these intensified international competition in this industry. As users became more used to motorization, moreover, they grew more demanding regarding the range of choice, frequency of model change, speed in delivery, reliability, comfort, etc.

Against this general background, the technological trend tended to vary depending on the sector. The body and final assembly lines require the greatest flexibility. Parts and components consist of two different groups: standardized mass production items which do not need flexibility of production facilities and differentiated items which require flexibility in their production. Enging blocks and transmission machining shops, for example, need much less flexibility and the same machinery can be used for many years.

Production of NC machine tools in France rose from 535 units in 1974 to
1068 units in 1978 and 1145 units in 1982. They are mostly lathes and other metal-cutting machines. NC machine tools account for less than 15 per cent of the total domestic machine tool shipments. The number of NC machine tools used in French industries was estimated at 10,500 in 1981. Of this total, about 2650 or approximately 25 per cent belonged to the automobile industry and slightly less than 30 per cent to small and medium-sized enterprises. However, many NCs attached to these machines seem to be of relatively unsophisticated kinds (manual, hydraulic, electrical, etc.), not based on microelectronics. Three flexible manufacturing systems have been installed so far, at RVI’s Bouthéon plant, Citroën’s Meudon plant and Peugeot’s Poissy plant (flexible spot-welding line) as pilot projects partly supported by the Government. With regard to CAD/CAM technology, in contrast, France is believed to be among the forerunners. Recently Renault developed a robot sculptor, which is claimed to halve the time and costs of designing a new vehicle.

We have already noted the closeness of the AFRI figures to the robotization data supplied by the assemblers, and argued that it might suggest a very limited use of robots among component producers and subcontractors. Scattered pieces of evidence cited below support this interpretation. The diffusion of NC machine tools among small and medium-sized enterprises appears also to be modest.

According to a survey conducted in February–March 1980, only 13 per cent of the firms with 10–500 employees in the mechanical engineering industry used such machine tools. The proportion was higher in larger size groups (Table 4). The most commonly used NC machine tools were lathes, which accounted for 41 per cent of the total, followed by milling machines (18

<table>
<thead>
<tr>
<th>Firm size (no. of employees)</th>
<th>No. of sample firms in 1980 survey</th>
<th>% of sample firms</th>
<th>Actually using 1978</th>
<th>Favourable to their introduction 1978</th>
<th>Opposed to their introduction 1978</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–49</td>
<td>414</td>
<td>15</td>
<td>17</td>
<td>80</td>
<td>73</td>
</tr>
<tr>
<td>50–99</td>
<td>148</td>
<td>30</td>
<td>24</td>
<td>58</td>
<td>63</td>
</tr>
<tr>
<td>100–199</td>
<td>123</td>
<td>33</td>
<td>26</td>
<td>51</td>
<td>54</td>
</tr>
<tr>
<td>200–500</td>
<td>77</td>
<td>24</td>
<td>25</td>
<td>54</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>762</td>
<td>19</td>
<td>18</td>
<td>73</td>
<td>69</td>
</tr>
</tbody>
</table>

*The figures for 1978 are based on an earlier survey conducted by the same institute.

per cent), drilling machines and forming (including punching) machines (12 per cent each) and machining centres (11 per cent). It is notable that in the same year 69 per cent of the sample firms were opposed to the introduction of NC machine tools. Small scales of production, need for a large investment and uncertain profitability were the reasons most frequently mentioned. However, 57 per cent of the entrepreneurs who did not want to introduce such machines failed to specify any reason.\textsuperscript{30} Probably psychological inhibition was the most important cause. In a 1982 survey, NC machine tools were used by 27–35 per cent of the sample firms in the transport equipment, metal-working and mechanical engineering industries, and by about 15 per cent of the foundries.\textsuperscript{31} It is not clear, however, how many used microelectronics-based numerical control devices. A survey in 1983 which included thirteen auto-parts and components manufacturers discovered that they had started introducing microelectronics-based automation around 1979, but the level of modernization varied widely from one firm to another. No flexible manufacturing system was observed at component manufacturers' plants nor were robots, although special-purpose machines with programmable controllers and microelectronic moulding presses were rather common.\textsuperscript{32}

In fact, what is at issue in France is still automation in general, not microelectronic technologies in particular. Use of automatic machines among small and medium-sized enterprises is still modest. In biennial surveys conducted by the Crédit d'Équipement des Petites et Moyennes Entreprises (CEPME),\textsuperscript{33} 52 per cent of the sample firms reported using automatic equipment in 1980 and 58 per cent in both 1982 and 1984.\textsuperscript{34} In 1984, only two-thirds of the metal engineering firms and less than half of the foundries used at least one automatic machine and only 5 per cent of the sample firms had programmable robots. The situation in the different size groups is shown in Table 5.

<table>
<thead>
<tr>
<th>Firm size (no. of employees)</th>
<th>Manipulators and/or robots</th>
<th>Other automatic machines</th>
<th>Machines collectively automatized</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–50</td>
<td>8</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>50–100</td>
<td>8</td>
<td>47</td>
<td>15</td>
</tr>
<tr>
<td>100–200</td>
<td>8</td>
<td>67</td>
<td>31</td>
</tr>
<tr>
<td>200–500</td>
<td>21</td>
<td>76</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>9 (5)\textsuperscript{a}</td>
<td>44</td>
<td>20</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The figure in parentheses relates to programmable robots.

3 CONSTRAINTS ON ROBOTIZATION

The biggest constraint on the diffusion of robots has been the limitations of the machines themselves. Robots are, however, at the confluence of various technologies which keep improving and adding new functions and capacities. Some people believe that no fundamental technological limit exists, although considerable human and other resources will be required for R&D. Such a view tends to give rise to two contrasting investment policies in the immediate future. On the one hand, it may encourage an early adoption of robots to benefit from the learning effect of different vintages of robots, constrained by the stock of existing equipment and the availability of investment funds. On the other hand, potential investors may feel that they might well wait for more sophisticated robots. The anticipation that the price of robots will continue to decline also tends to encourage this attitude.

Regarding the production processes for which robots are already available, it seems a priori evident that the more important the technological advantage (in terms of efficiency) of the new equipment, the faster its diffusion is likely to be, other things remaining equal. In reality, however, a large technological advantage tends to be offset, to a smaller or larger degree, by a 'jump' in the degree of technological sophistication, which gives rise to various constraints on the adoption of the new technology. The superiority of the robot over conventional automation machinery needs to be determined by taking both factors into account. Views are split. Some firms consider robotization as only a step in a continuous process of sophistication of automation technology and do not believe that there is any big 'jump'. Others feel that the technological gap is indeed very serious.

Those who have been using robots for several years (e.g. the automobile assemblers) generally take the first view. Most auto-parts manufacturers and subcontractors, among whom diffusion of robots has been very limited, tend to take the second view. They recognize great technical advantages of robots but, at the same time, have technical difficulty in applying the new technology. Firms also find it difficult to make a decision because of uncertainties concerning the technical performance of the new equipment and because new technical alternatives are likely to emerge in due course.35

Another problem is organizational. Robotization seems relatively easy in two different situations: first, where a high degree of automation has already been attained before the introduction of robots, and second, where robots are introduced in a specific process (e.g. material handling) without affecting the earlier or later processes. In practice these cases are rare, and robotization usually requires a considerable organizational change. For smaller component makers and subcontractors, this seems to be a major problem: in a survey in 1982, 56 per cent of the sample firms mentioned organizational problems as a major constraint.36 The assemblers usually introduce robots at the time of launching new models and/or expanding the production capacities. Thus they seem to encounter the problem of organizational readjustment less frequently.
For parts and component makers and subcontractors, the basic constraint is financial. In the CEPME survey in 1984,37 74 per cent of the sample firms mentioned ‘too high prices of equipment’ as a constraint on automation (of any kind) and 50 per cent financing and pay-off problems. The problem is partly cyclical and partly structural. It is cyclical to the extent that it has been aggravated by the depressed demand. It is structural to the extent that the assemblers squeeze subcontractors’ earnings and profits (cf Section 1 above). Whatever the cause of the problem, it reduces these firms investment capacity, while the lack of long-term purchasing policy and commitment on the part of the assemblers increases uncertainty and risk in investment.

4 IMPACT OF THE NEW TECHNOLOGY

(i) Employment and skill requirements

Robotization is often considered as a form of substitution of capital for labour. In reality, however, robots may or may not replace workers, since they can replace other automatic machines. In the French automobile industry, robots have been introduced so far mostly to replace automatic machines. This is clear from the information in Table 6, which we obtained at Renault. The same source believed that only 25–30 per cent of the robots installed in the industry had replaced or substituted for labour, approximately two workers per robot in each shift. By applying these figures to the total number of robots installed in the industry (797), it might be argued that about 950 workers were replaced by the robots installed by the end of 1984, in two shifts. (It should be noted, however, that our interviewee at PSA refused to indicate any estimates of such proportion and ratio on the ground that robotization was not isolable from other changes, which will be discussed shortly.) The overall quantum of the labour-saving effect of microelectronics is larger than this, since we need to take account of NC machine tools, CAD/CAM and programmable controllers and other equipment which help enhance the organizational efficiency. At the same time, the real impact on employment is different from the apparent effect measured in terms of the number of workposts lost when and where the microelectronic equipment was introduced.

First, the diffusion of such new equipment advances simultaneously with other important changes in the production facilities, work organization, product designs, etc. To compare the first Renault 5 introduced in 1971 with the new Renault 5 introduced in 1984, for example, the time required for assembly declined from 28 to 20 hours. In the meantime, welding spots decreased from 4003 to 3400. This was made possible by a number of factors: rationalization of the vehicle design and cut in the number of parts to be assembled, the improved quality of welding work and substitution of plastic for metal sheet as a material for body-parts. The proportion of plastic in the total weight of the vehicle increased at an accelerated rate, from 5 per cent for the first Renault 5 to 10 per cent for the new Renault 5.38 In addition to these,
Table 6: Changes in the spot-welding techniques at Renault (% of total welding spots on the vehicle)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>20</td>
<td>20</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Automatic machines (e.g. multispot welding machines)</td>
<td>75</td>
<td>40</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Robots</td>
<td>5</td>
<td>40</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
1. The exact percentage composition varies to some extent, depending on the specification of individual vehicles, even within the same model.
2. The total number of welding spots declined over time.

From information supplied by RNUR.

there have been innumerable other changes. Regarding technological progress, one of the most important areas of recent innovation seems to be stamping. Organizational rationalization is also extensive. Our respondent at Renault stated that three factors contributed to the increase in productivity more or less equally: rationalization of the product design, improvements in the organization of work and modernization of production technologies. Microelectronic innovation was only one of many elements of the last item, although it also helped in the rationalization of product designing (e.g. CAD/CAM) and work organization (e.g. programmable controllers).

Second, with the introduction of the new technology, new types of work (e.g. more complex work) may be added, and the amount of conventional work may increase. The microelectronic technology tends to encourage firms to undertake greater amounts of developmental work (e.g. larger numbers of prototypes of cars and components). Increased degrees of diversification of individual car models, which are associated with the microelectronic production technology, imply larger amounts of organizational work as well as more developmental work. This point, which has been noted in the chapter on the Japanese industry in this volume, was stressed by a representative of PSA. To take a model this group put on the market in 1985, for example, there are 270 versions with different body shapes, numbers of doors and/or motors which meet varied safety and environmental standards set by user countries. These 270 versions are further differentiated with respect to different parts and components (gear box, brake, wheel, ventilator, roof (open or closed), window glass, regulator, etc.). Because of the multiplicity of both parts and components and their specifications, there are some 10 000 variations of this model, without counting the differences in the colour and minor options. The
microelectronic technology has made such a degree of product differentiation economically feasible. However, the total amount of labour requirements off the production line can grow larger per unit of final output. Also, the numbers of production lines and workshops can increase. It would therefore be wrong if one evaluated the employment effect of the new technology simply by comparing the numbers of workers or work hours per vehicle on individual production lines before and after the introduction of the technology (e.g. robots).

It is by now common knowledge that the new technology creates demand for programmers, engineers and other staff. This may be illustrated with reference to findings of a comparative study\(^{39}\) of two spheroidal graphite casting plants. In 1979 PSA transferred this operation from its old Clichy plant to a new plant in Charleville, which is equipped with modern facilities including a robot. The product did not change and the volume of production remained constant at 39.2 tonnes a day. Because of the modern equipment and organization, the number of production workers declined drastically from 257 to 137 and the size of administrative and other service staff was cut down from 61 to 52. In contrast, the number of maintenance personnel rose from 46 to 66. The exact amount of such new manpower requirements varies from case to case, even within the same firm: the larger the number of robots installed together on one line, the smaller such requirements per robot.\(^{40}\)

Although the media tend to associate the recent decline of employment in this industry with the diffusion of the new technology,\(^{41}\) the principal explanation for the shrinking employment in the French automobile industry is the decline in production. Even if output per worker had remained constant at 8.5 vehicles between 1978 and 1984, the 1984 level of automobile production would have provided 360,300 jobs, or 52,300 fewer than in 1978. This corresponds to 63 per cent of the total number of jobs lost during the period (83,100).

The crucial importance of the production level is not fully appreciated even by academic researchers. In a recent study,\(^{42}\) for example, a comparison was made between Peugeot's Sochaux and Mulhouse plants. The author of this study argued that the latter plant had been modernized with a sizeable capital investment, notably through installation of 60 robots, 50 microprocessors and 150 programmable controllers, while the first plant managed to reduce the number of employees from 42,000 in 1979 to 29,000 by the end of 1983 with little investment. At the latter, the 'increase in productivity' was achieved, according to the author, by means of minor devices of automation, changes in work organization, reduction of absenteeism and improvements in the quality of the products. Our interviewee at Sochaux, however, categorically rejected this argument and attributed the redundancy to the fall in the daily rate of production from 1900–2000 units in 1979 down to 1000–1100 by the first five months of 1985, when the number of employees was 28,000. Absenteeism increased from 10.2 to 11.5 per cent between 1979 and 1983. The number of vehicles produced per direct production worker declined from 14.7
Microelectronics, Automation and Employment in the Automobile Industry

in 1979 to below 12 units during 1980–82. In 1984 it was still less (14.5 units) than in 1979.

Microelectronic innovation in production technology tends to reduce the demand for unskilled direct production workers while increasing that for highly trained indirect workers, notably technicians and engineers for maintenance and R&D. Intensification of competition among automobile manufacturers induces more frequent model changes, which also stimulate demand for R&D staff. Peugeot reduced its workforce by 7000 in 1983, 5000 through early retirement and 2000 through dismissal. Most of the latter were immigrants. At the time of our visit, the company anticipated the departure of about 3000 more immigrants before the end of August 1985. It also expected the total number of direct production workers to shrink by about 20 per cent in the near future and the proportion of unskilled workers to fall from 50 to 30 per cent. Consequently, the proportions of semi-skilled and skilled workers would rise from 35 to 50 per cent and from 15 to 20 per cent, respectively. Renault reportedly intends to expand the number of highly trained technicians, engineers and cadres for R&D from 7200 in 1984 to nearly 8000 by 1988, although the number of unskilled and, to some extent, also semi-skilled workers is likely to be reduced further. Thus, it is unskilled workers, and older workers and immigrants in particular, that have lost their jobs as a result of the current effort at rationalization and adaptation to the market situation.

(ii) Work organization

Where robots and other microelectronic technologies have been introduced on a large scale, work organization has also tended to change considerably, at both workshop and company levels. On a conventional production line, each worker has a direct contact with workpieces. In a new system, his task becomes the supervision of machines rather than the workpieces. At the same time, in order to make the most out of ‘flexible’ machines, each machine operator is required to take charge of day-to-day maintenance and simple repair work. In the old system, each worker also had control over the speed of his work and was able to accumulate his ‘margin time’ by finishing a given amount of work quickly. Under the new system, he will have no control over the speed, which is centrally fixed. To permit individual workers to leave the line occasionally, they are expected to take responsibility collectively for their work. This presupposes their ‘polyvalence’ (i.e. possession of combined abilities), which facilitates interchanging of responsibilities. In brief, the new technology calls for a new type of worker, namely one who has not only a greater technical knowledge, but a greater adaptability to new situations, an ability to respond quickly to technical problems, as well as a capacity for team work, rather than one who possesses physical strength and individual work capacity, which used to be the main criteria in recruitment.

In order to help workers to prepare themselves for the new situation, training is required for skill upgrading. Considerable efforts have been made
at major companies, often with support from the State. For example, 3060 million man-hours were being spent at the cost of about 50 million francs (salaries and direct training cost) at Talbot (Poissy) in connection with a recently introduced model. This was equivalent to 4 per cent of the total amount of investment related to this new model.

At the company level, too, things appear to be changing. In the French automobile firms, the various functional departments traditionally operated quite independently from each other. With the advance of robotization, however, their organizational structures began to open up, both outwards and within the firm. In the case of Renault, communication among the product design, production engineering and production processes departments became closer, especially at the engineers’ level. Such change originated from Douai plant in the late 1970s.

They also developed links with outside partners and research centres, especially after 1980. We have already mentioned examples of collaboration between Renault and PSA, and their increasing dialogue with component manufacturers and subcontractors, in Section 1. It is, however, not clear to what extent these new developments have been stimulated by the new technology and how much by increased international competition and a consequent sense of ‘crisis’. Our own impression is that the latter is a more direct influencing factor. We will elaborate on this point in Section 6 below.

(iii) Workers’ attitude

At first workers were hostile to any change in the organization of work, but they became increasingly persuaded that without new technology no company or industry could survive. The employers—particularly Renault—have been publicising the image of robots as a symbol of both ‘high-tech’ revolution and greater international competitiveness. The first seems to appeal particularly to workers at the workshop level, giving rise to an image of robot operators as new labour élites and to a certain pride regarding the technical performance of the plant. This ‘high-tech’ image is particularly noticeable with the Renault group because most of their robots are built in-house. The second element—international competitiveness—appeals more to the trade unionists, who are aware of the important bearing it has on future job opportunities in this highly export-dependent industry.

Workers’ pride goes with a sense of achievement within the team which has had to start the application of the new equipment and make it operational. After the enthusiasm of the initial period is gone, however, daily operations become repetitive and routine and workers become disillusioned. On entirely automated lines, workers also feel somewhat lost and isolated. This is aggravated by the transmission of instructions via computerized information systems, which will increase in the course of time.

The trade unions’ acceptance of robots is not unconditional, either. Because a higher productivity can result in loss of jobs, the introduction of the
new technology has to be negotiated. Recently, new labour legislation (*Lois Auroux*, 1982) was introduced to encourage consultation on technological issues. In 1983, Renault launched a very large consultation programme entitled MIDES (*Mutations Industrielles et Dynamiques Sociales*). The consultation under this programme covers the following subjects:

1. Towards a new industrial system;
2. Industrial changes in the field of production;
3. Industrial changes in the field of research and management;
4. Products, techniques and social evolutions;
5. Renault and competitiveness;
6. Evolutions of industrial labour and social evolutions;
7. Geographical decentralization, new techniques and social evolution.

5 GOVERNMENT POLICY

In order to (i) encourage the development and diffusion of microelectronic equipment such as robots and NC machine tools, and (ii) assist the industries in their rationalization efforts, the French Government has different programmes. Those which are intended for objective (i) may be called 'positive' and those related to objective (ii) 'passive'. In so far as the automobile industry is concerned, the following appear to be the most relevant.

(i) **Positive programmes**

The 'programme productique' has two objectives: the encouragement of the diffusion of microelectronic technologies especially in the industrial sector, and the promotion of development and production of related equipment and software (CAD, robots, peripheral equipment such as visors, NC machine tools, FMS, engineering software related to them, etc.). The main policy instrument in this programme is the *Fonds Industriel de Modernisation* (FIM), which provides users of new technology with low interest rate loans for capital investment and for training and subsidizes equipment suppliers' R&D and capital investment. Another policy instrument is the *Opération Pilote*, whereby the Government shares the investment cost to help reduce business risk involved in new technology, for example the flexible manufacturing systems at RVI's Bouthéon plant for the production of gear boxes and Citroën's Meudon plant for engine block production. For small firms the *Opération Aide Premier Equipement* is available for the acquisition of NC machine tools. In fact, different financial institutes have special loan programmes for similar purposes. One example is *Prêts Efficacité des Equipements-Productique* of the Crédit d'Equipement des PME. During the four-year period 1981–84, a total of 4971 enterprises benefited from this programme and the aggregate amount of loans totalled 3424 million francs.

The Centre de Formation Technologique des Travailleurs de l'Automobile
(CFTTA) was set up in May 1984, in the wake of the industrial disputes at Talbot (December 1983) and Citroën (April 1984), who had announced their intention to reduce the numbers of their employees by 4140 and 6000, respectively. The Centre is intended to 'develop a vast training programme to meet the needs of the automobile manufacturing firms and their workers'. So far, however, it has not been very active. The Government also envisages the expansion of supplementary training programmes in 'productique' to take in 100,000 workers from 1986 onwards as compared with 11,000 in 1984.

(ii) Passive programmes

To assist the industry in its rationalization effort aimed at the elimination of surplus labour, the Government has the following main policy instruments.

The Aide emploi subsidizes individual firms’ retraining of redundant workers for twelve months, using the Fonds National pour Formation. If the worker does not receive any offer of a job or if he refuses a job offered after the retraining period, he is dismissed. This was applied, for example, to 1900 workers in 1983 at Talbot and 1900 at Citroën in 1984. The Chômage technique permits the closure of a plant or part of a plant by providing a state subsidy at the hourly rate of 9 francs per worker, while the employer continues to pay 60 per cent of his normal wage. This is applicable for up to 600 hours per worker each year (i.e. 25–30 per cent of the total working time). At Peugeot’s Sochaux Plant, Chômage technique was applied for 68 days between 1979 and 1984 (70 per cent in 1980–1981) and 24 days in the first 5.5 months of 1985. For early retirement two funds are available: Fonds national pour l'emploi (FNE) for involuntary retirement and the Système Garanties de Ressources for voluntary retirement. In addition, under the programme of Opération d'Emploi Solidarité, the State pays part of the retirement bonus to encourage workers to retire at the age of 50–55 instead of 60. This is intended to help replace older workers with younger ones with skills and knowledge required for automation.

Under the programme Aide au Retour des Immigrés, the following allowances are payable to a returning worker: (a) the travel cost, (b) the repatriation allowance of 2500 francs for single workers and up to 6700 francs for those with their family from other European countries, and 4000 francs for single workers and up to 10,000 francs for those with their family from outside Europe, and (c) financial support towards reemployment in the home country of up to 20,000 francs including the cost of training in France or at home or professional material purchased in France (e.g. a mini-truck). This official programme supplements two other schemes for which the returning worker is eligible simultaneously: a statutory grant from the unemployment insurance scheme and assistance from the worker’s last employer, which will be provided in accordance with the agreement between the employer and the Government or the Office National d’Immigration (ONI).

Originating in the state assistance offered to those immigrants who lost
their jobs at the Poissy plant of Talbot in December 1983 and the Aulnay-sous-Bois plant of Citroën a few months later, the programme was initially applied to major plants in the automobile industry. Subsequently other industries and smaller enterprises began to benefit from it. The average number of workers involved in each agreement tends to decline. By the end of August 1985, 961 agreements had been signed between enterprises and the State at either national or departmental level. Of this total, 44 per cent belonged to the automobile and auto-parts manufacturing industry. By the same date, 9665 workers had returned to their countries, and the Office National de l'Immigration anticipated that 18,000–20,000 would go by the end of 1985.54

At the regional level, regional authorities have programmes to assist in the transfer of workers to other establishments within the firm or within the same company group. This programme, however, seems to be seriously constrained by the workers' reluctance to accept such an offer. For example, all of the 50 workers who were offered incentives for a transfer from Sochaux to other plants refused the offer.

6 SUMMARY AND CONCLUSIONS

Supported by a variety of programmes which the Government has introduced for technological modernization and organizational rationalization, the automobile industry, as well as other industries in France, is trying to increase its productivity by eliminating surplus labour. Employment in the assembly sector has declined slowly but steadily since 1978, through non-recruitment of new workers, early retirement and encouragement of voluntary return of immigrant workers. The parts and component sector has followed a similar trend slightly less steadily. Consequently, the number of vehicles produced per worker increased over time, from 8.8 units in 1979–80 to 9.4 units or so in 1983–84. To take two years with approximately the same annual output, 1974 and 1984, output per worker rose by 16 per cent over this 11-year period.

It is, however, difficult to say that microelectronics has been a principal cause of labour redundancy in this industry. For one thing, the diffusion of the new technology has been limited, especially outside the plants of the two major assemblers. In 1984, this industry is believed to have had 797 robots. If we apply the proportion of labour-replacing robots in the total (30 per cent) and their worker-replacement ratio (4 in two shifts) as reported by Renault, the number of workers replaced by these robots is estimated at 950. This is just over 1 per cent of the total number of jobs lost in the industry between 1978 and 1984 (83,100). Even allowing for the effects of the NC machine tools, CAD/CAM and microelectronic controllers that help increase efficiency of work organization in plants, the employment impact of the new technology seems to have been marginal. Far more significant are the effects of rationalization of work organization, product design and innumerable
technological improvements which are unrelated or only indirectly related to microelectronics. In the light of the above, one tends to feel sympathy, at least in some cases, with the Secretary General of the Fédération FO de la Métallurgie, who suggested that robotization had been used as a pretext for mass lay-off, although visits to plants in this industry do give rise to an impression that overmanning is a real problem.

At the same time, some workers lose their jobs because of their reluctance to accept a transfer to a new workpost, as the experience at PSA’s Sochaux plant discussed above suggests. The phenomenon seems to prevail in French industries in general: ‘Anybody who is in charge of the matter knows that in France there is a bottleneck—often inexplicable—in transferring certain employees to other establishments...’

More flexible work organization based on a concept of team work, the mounting enthusiasm for training, for example to create a ‘polyvalent’ workforce, improvement in interdepartmental and interfirm relationships aimed at greater cooperation, movements towards a closer partnership between parent firms and subcontractors—all these ‘new’ concepts and changes are often associated with the new technology. In our view, this is not quite correct. Basically, they have been brought about by international competition, of which France somehow grew suddenly aware. The new technology is only one of the instruments used in the effort at adaptation to this new situation. This interpretation seems to be supported by at least two of our findings. First, our interviewee at Peugeot explained his company’s motivation for the application of robots and NC machine tools by saying that increasing competition demanded flexibility in their production system and better/higher product quality (cf Section 2 above). Second, as is clear from various surveys published in *Industries et Techniques*, at least in the small and medium-sized sector, the current modernization effort is not focused specifically on microelectronics but on automation in general.

Looked at from another viewpoint, this also implies that, when all the necessary organizational and structural adjustments have been made, the French automobile industry may be able to make a major technological jump (in terms of productivity), at the risk of creating serious employment problems, especially for new school leavers.

ACKNOWLEDGEMENTS

I am indebted to Professor Jacques de Bandt, who inspired me in the present study and provided some useful bibliographical information. For the preparation of this study, in May–June 1985, I visited Renault’s head office and Flins plant, Citroën’s Rennes plant, Peugeot’s Paris office and plants in Sochaux and Mulhouse, as well as various government and other institutes in Paris. I am grateful to Renault and PSA for their kind cooperation. My special thanks are also due to the Chambre Syndicale des Constructeurs d’Automobiles (CSCA), which permitted access to their files. Mr Christian Mory of CSCA
and Dr Benjamin Coriat of University of Paris VII kindly read an earlier draft of this chapter very carefully, and made valuable suggestions which helped to improve it. Any remaining shortcomings are my sole responsibility.

NOTES

1 'L'industrie automobile française', Liaisons Sociales, No. 115/84, 24 October 1984.

2 The level of investment in French industries declined drastically after the first oil shock of 1973/74 and has never recovered since. This has been the case especially with the larger enterprises. The rate of investment by enterprises with 500 or more employees fell from about 25 per cent of the value added in 1971-73 to around 15 per cent in 1974-76 and continued to fall further. Among the enterprises with 100-499 employees, it decreased from over 15 per cent to about 13 per cent and further down to just over 10 per cent towards the end of the decade. In the size group with 20–99 employees, the investment rate also declined but much more modestly, from just below 15 per cent to just over 10 per cent (Delattre, 1982).


4 The reduced employment at the assemblers is attributable partially to the transfer of certain operations to their subsidiaries and suppliers such as La Française de Mécanique and la Société des Usines Chausson. See Journal Officiel de la République Française, 17 August 1984, p. 58.

5 Le Monde, 14 and 18 June 1985. The French automobile manufacturers' rationalization programmes aimed at trimming overmanning seem to have been considerably influenced by the experience of FIAT, which is discussed in Chapter VI (see 'Le plan de M. Besse pour redresser Renault: Réalisme à l'italienne', Le Monde, 20 June 1985).

6 CFTC (1985) p. 28.

7 Hereafter we will use 'Renault' and 'PSA' to refer to the two groups.

8 Journal Officiel de la République Française, 17 August 1984, pp. 46-47. The two groups' collaboration in research takes place through the Laboratoire de Physiologie et de Biomécanique du Docteur Tarrière, the Groupement Scientifique Moteurs (GSM), the Institut de Développement des Composants Automobiles (IDICA) and the Société Machines Françaises Lourdes (MFL).

9 As note 8, p. 57.

10 De Banville and Chanaron (1985), p. 30. The corresponding figures are 12 per cent for FIAT, 16 per cent for Alfa Romeo, 20 per cent for Volkswagen, 20–30 per cent for Ford in Europe and 50 per cent for Saab (Bianchi, 1983, p. 39).

11 As note 8, p. 51.

12 A recent survey of auto-component producers found that a 7 per cent decline in automobile production had sometimes resulted in a 30 per cent decline in component producers' work, because the assemblers operated using stocked supplies. The total number of workers at thirteen auto-component manufacturers included in this survey fell from over 8600 to 6750, or by 16 per cent (Gorgeu and Mathieu, 1984, pp. 24-25).

13 As note 8, pp. 51-55.


15 As note 8, p. 57.


17 As note 8, p. 57.

19 As note 8.
21 As note 8, p. 77.
22 AFRI (Association Francaise de Robotique Industrielle): Statistiques 1985 (Paris). The data are based on a survey of 46 French robot builders and 36 foreign builders or importers. 'Robots' includes programmable robots and intelligent robots, but not manual manipulators and fixed- and variable-sequence automatic manipulators.
24 Information supplied by the company. The substantial increase during the 22-month period seems to be largely attributable to the renovation of the company's Poissy plant.
27 As note 8, p. 79.
29 'Robot sculptor takes automated vehicle design a step further', Financial Times (London), 9 September 1985.
33 Industries et Techniques/special robotique, December 1984. The sample of the 1984 survey consisted of 308 enterprises with 10–499 employees. These biennial surveys are conducted in collaboration with the Agence pour le Développement de l'informatique (ADL) and Industries et Techniques.
34 Because the samples in different years are not comparable, however, the inter-temporal changes in these figures do not mean much. For example, the sample in the 1980 survey was 582 firms with fewer than 600 employees, as compared with 308 enterprises with 10–499 employees in 1984. See Industries et Techniques: 'Les P.M.I.: A Petit Pas', 31 December 1980.
37 As note 33, p. III.
38 AVEC, Mensuel Renault, 26 April 1985.
40 Where the microelectronic equipment is produced within the automobile industry, this will also give rise to new jobs. In France, Renault is the largest robot producer, and Coriat (1983) estimates the number of its employees engaged in robot production at 60. PSA also builds simpler robots (cf Coriat, 1984, Ch. II). Out of 797 robots installed in the automobile industry in 1984, 80 per cent (638) had been built in France, according to AFRI. Coriat (1983) estimates the total number of workers engaged in production of robots and manipulators at about 400.
41 See, for example, 'La guerre technologique dans l'automobile a déjà supprimé 50,000 emplois (The technology war in the automobile industry has already eliminated 50,000 jobs)', in Le Quotidien, 24 August 1984.
42 Santilli in Azoulay, Santilli and Du Tertre (1984), based on a survey conducted between February and June 1984.
43 Such redundancy was attributed largely to the decline in the production level since 1978/79, and to organizational rationalization which started in 1978.
44 Ten years' education and training for 'unskilled' and twelve years' education and training for 'semi-skilled'.
45 Cf the above-cited report in Le Quotidien, 24 August 1984 (note 41).
46 This subsection is largely based on De Bandt (1984).
Sometimes the argument has been carried a bit too far and given rise to a myth: '... in 1982, each worker of the Peugeot Group produced, on an average, 6.8 vehicles, while an employee at Fiat or General Motors produced 11 and at Toyota, in Japan, where robotization is almost complete, these records were surpassed by producing 54 cars per person' (our italics) ('Citroën: ça dégraisse', Express, 17 February 1984, p. 43). The above description of the Japanese situation is far from reality, as can be surmised from the chapter on the Japanese industry in this volume. The comparison of the numbers of vehicles produced per worker at different assemblers' plants means little, because the degree of integration and other conditions are different. To understand clearly the significance of journalistic reports like this, one should realize that, although the Japanese share of the French automobile market is less than 3 per cent, the modernization programme of the French Government is built around the concept of 'défi japonais' (see, for example, Dalle Report).

For a comprehensive description of the government programme, see Journal Officiel, 30 December 1983.

French productique more or less corresponds to Japanese 'mecha-tronics' or English 'computer instructed manufacture (CIM)', which includes not only informatique or microelectronics but also mechanical technology or equipment to which microelectronic devices are attached.

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CHAPTER VI

Robots, Employment and Industrial Relations in the Italian Automobile Industry

Francesco Silva, Piero Ferri and Aldo Enrietti

After a review of the structure and trends of the automobile industry in Italy (Section 1), this study examines the employment impact of microelectronic technologies on this industry by means of case studies of a number of selected firms. Our analysis of the assembly sector (Section 2) will be concerned mainly with FIAT because of its overwhelming position in the industry. Our treatment of the auto-parts sector (Section 3) will be partial, because of the lack of systematic data. Section 4 contains a summary and conclusions.

1 TRENDS AND STRUCTURE OF THE INDUSTRY

(i) The assembly sector

Automobile production in Italy grew steadily from 127 thousand units to 1958 thousand units between 1950 and 1973. Thereafter, it declined (Table 1). Many factors explain this negative trend: saturation of the domestic market, slowdown of GDP growth, increases in the real prices of both automobiles and gasoline, etc. In 1980 and 1981 domestic demand sharply increased, but in the following two years it decreased again. The ratio of imports to domestic demand rose from 5 per cent to 41 per cent between 1960 and 1983, while that of exports to domestic demand fell from 52 per cent to 26 per cent (Table 2). The declining exports/domestic demand ratio and the rising imports/domestic demand ratio imply a loss of international competitiveness of the Italian industry. This trend, however, reversed in 1984 as a result of successful efforts at cutting costs and introducing new models.

The Italian automobile industry is highly concentrated. In 1983, FIAT produced 83 per cent of national production. There is no foreign assembler in Italy. FIAT's share of the domestic market fell to a minimum (50 per cent) by 1979 and then rose again (55.4 per cent in 1983). In the late 1970s Renault replaced Alfa Romeo as the second largest seller on the Italian market.

Another important feature of this industry is the geographical concentra-
Table 1: Production, employment and investment in the Italian automobile and auto-parts industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Production ('000 vehicles)</th>
<th>Employment ('000 workers)</th>
<th>Investment (million lire)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>Blue-collar (2)</td>
<td>White-collar (3)</td>
</tr>
<tr>
<td>1972</td>
<td>1839.8</td>
<td>204.4</td>
<td>49.6</td>
</tr>
<tr>
<td>1973</td>
<td>1958.0</td>
<td>235.1</td>
<td>55.1</td>
</tr>
<tr>
<td>1974</td>
<td>1772.5</td>
<td>224.0</td>
<td>49.9</td>
</tr>
<tr>
<td>1975</td>
<td>1458.6</td>
<td>204.5</td>
<td>48.1</td>
</tr>
<tr>
<td>1976</td>
<td>1590.7</td>
<td>214.4</td>
<td>52.8</td>
</tr>
<tr>
<td>1977</td>
<td>1584.5</td>
<td>227.4</td>
<td>57.7</td>
</tr>
<tr>
<td>1978</td>
<td>1656.6</td>
<td>224.6</td>
<td>57.9</td>
</tr>
<tr>
<td>1979</td>
<td>1632.3</td>
<td>230.5</td>
<td>58.8</td>
</tr>
<tr>
<td>1980</td>
<td>1610.3</td>
<td>226.7</td>
<td>58.4</td>
</tr>
<tr>
<td>1981</td>
<td>1433.7</td>
<td>213.3</td>
<td>56.2</td>
</tr>
<tr>
<td>1982</td>
<td>1453.0</td>
<td>197.6</td>
<td>56.7</td>
</tr>
<tr>
<td>1983</td>
<td>1575.2</td>
<td>179.5</td>
<td>51.5</td>
</tr>
<tr>
<td>1984</td>
<td>1601.1</td>
<td>171.9</td>
<td>47.4</td>
</tr>
</tbody>
</table>

From Associazione Nazionale fra Industrie Automobilistiche (ANFIA): L'Auto in Cifre, various years.

At the beginning of the 1970s, the northern provinces of Piedmont and Lombardy accounted for over 80 per cent of the total employment in the industry. Over the next ten years, central and southern parts of the country gained somewhat in importance, but 70 per cent of the labour force is still located in the north.

Table 1 shows the trends of employment and investment not only by the assemblers but also by parts manufacturers. The assemblers account for over 60 per cent of total employment, while their share of investment is likely to be even higher.

Total employment declined sharply twice, by 13 per cent in 1973–75 and by 20 per cent in 1979–83. There is a significant difference between these two

Table 2: Domestic passenger car demand, production, imports and exports ('000 vehicles)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Domestic demand</td>
<td>381</td>
<td>1364</td>
<td>1713</td>
<td>1582</td>
<td>1636</td>
</tr>
<tr>
<td>2. Production</td>
<td>596</td>
<td>1720</td>
<td>1445</td>
<td>1396</td>
<td>1439</td>
</tr>
<tr>
<td>3. Imports as % of (1)</td>
<td>5.0</td>
<td>27.7</td>
<td>39.9</td>
<td>40.7</td>
<td>36.9</td>
</tr>
<tr>
<td>4. Exports as % of (1)</td>
<td>51.9</td>
<td>46.3</td>
<td>29.7</td>
<td>26.0</td>
<td>29.4</td>
</tr>
</tbody>
</table>

For source see Table 1.
periods: while the first decline was a cyclical phenomenon, the second was a structural one. In the first case, employment recovered as the production of vehicles began to increase again. In the second case, employment continued to decline during 1983, while production increased by 7.8 per cent. As we shall see in Sections 2 and 3, the major factor causing this difference between the two periods was industrial relations. In the 1970s the trade unions successfully resisted the firms' efforts to increase labour productivity, while since 1980 the firms' bargaining power has become much stronger.

The amount of investment increased in money terms between 1972 and 1981 (+ 9.9 per cent per year) but not in real terms (− 6.5 per cent per year). A new commitment by FIAT to the industry was made clear in 1982, when its investment almost doubled compared with the year before. Most of the investment was of a capital-intensive labour-saving nature.

Until the early 1970s, the production technology in this industry developed towards standardization and mass production, based on special-purpose automatic machines. Automation advanced, typically relying on the transfer machines. Since each line of transfer machines is designed for a specific automobile model, it has to be replaced with a new line whenever a model change takes place. To save capital, the Italian firms tended to minimize such replacement investment, particularly in highly automated facilities such as engine plants. However, recent exogenous shocks to the industry—increased fuel prices, the slowdown in the growth of demand and the erosion of market shares as a result of intensified international competition—have more or less forced it to adopt more flexible production technology based on robots, programmable controllers and NC machine tools, which can cope with different models. The new technology will, in the long run, reduce capital requirements for model changes. The labour-saving effect of such ‘flexible automation’ seems to be smaller than that of the ‘fixed automation’ based on transfer machines introduced in the 1960s. While labour productivity increased by about 300 per cent during the 1960s as a result of the introduction of fixed automation, it is expected to increase by no more than 125 per cent during the 1980s with the robots and all kinds of other innovations in production and product technologies.

However, the introduction of microelectronics has resulted in remarkable cost reductions, not only in production processes but also in designing and product development. For instance, computer-aided design (CAD) of a certain mechanical part has cut down the designing time from 59 hours to seven hours, while the weight of the part is optimized at the same time.

(ii) The auto-parts sector

There are no comprehensive data on the structure of the auto-parts sector as a whole. Different institutes have published different estimates of its size. According to the official definition given by the Comitato Componentistica (Parts Committee), this sector consists of firms which provide finished pro-
ducts, including glass and tyres. These are destined for both the original parts market and the replacement parts market for passenger cars and commercial vehicles. The Comitato puts the total employment in this industry at approximately 160,000 in 1982, and its sales at about 6000 billion lire, of which approximately 80 per cent was realized in the passenger car market (60 per cent in the original parts market and 40 per cent in the replacement parts market). The Central Statistical Office (ISTAT) estimates the total employment in this sector to have been 192,000 in 1981.

Table 3 summarizes findings of two studies carried out in Piedmont and Lombardy, where the Italian automobile industry is heavily concentrated due to the location of FIAT and Alfa Romeo. In 1981, 46 per cent of the firms employed fewer than 50 workers, but these firms employed only 6 per cent of the sector's total labour force, while 3 per cent of the firms had more than 1000 workers and employed about 50 per cent of the total.

In Italy, there are three broad groups of auto-parts manufacturers. The first group consists of firms partially or totally controlled by foreign capital, mostly large multinational conglomerates such as ITT, Eaton, Associated Engineering, Valeo, Rockwell, Bendix, Michelin and Goodyear. About 50 firms belong to this group, employing approximately 52,000 workers. In terms of employment, this is the most important group. The second group of firms is controlled by FIAT (Gilardini, Comind, Weber, Magneti Marelli, Marelli Autronica, Borletti, Teksid), providing jobs for 43,000 workers. The third group consists of the firms belonging to small national groups and those which are independent. The median size of firms is 5000 workers in the second group, 1000 in the first group, 180 in that part of the third group which belongs to small national groups and 60 in the independent part of the third group.

Table 3: Employment in the auto-parts sector by firm size: Piedmont and Lombardy (1981)

<table>
<thead>
<tr>
<th>Firm size (no. of workers)</th>
<th>No. of firms (1)</th>
<th>%</th>
<th>No. of employees (2)</th>
<th>%</th>
<th>Average size (2)/(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–50</td>
<td>197</td>
<td>46.3</td>
<td>5567</td>
<td>6.0</td>
<td>28</td>
</tr>
<tr>
<td>51–100</td>
<td>85</td>
<td>20.0</td>
<td>6302</td>
<td>6.8</td>
<td>74</td>
</tr>
<tr>
<td>101–250</td>
<td>90</td>
<td>21.3</td>
<td>14273</td>
<td>15.5</td>
<td>158</td>
</tr>
<tr>
<td>251–500</td>
<td>28</td>
<td>6.6</td>
<td>10851</td>
<td>11.8</td>
<td>387</td>
</tr>
<tr>
<td>501–1000</td>
<td>12</td>
<td>2.8</td>
<td>9534</td>
<td>10.4</td>
<td>734</td>
</tr>
<tr>
<td>Over 1000</td>
<td>13</td>
<td>3.0</td>
<td>45542</td>
<td>49.4</td>
<td>3503</td>
</tr>
<tr>
<td>Total</td>
<td>425</td>
<td>100.0</td>
<td>92,059</td>
<td>100.0</td>
<td>216</td>
</tr>
</tbody>
</table>

Note
The firms producing glass and tyres are not included.

Technologically, 90 per cent of the firms in the first two groups have designing capacity and the remaining firms specialize in products which require high workmanship. In contrast, only 25 per cent of the firms in the third group possess designing capacity. The technological weakness of small firms has made it necessary for FIAT to increase its vertical integration. It also induced foreign producers of sophisticated parts to invest in Italy.

Within the European Economic Community, Italy is the fourth largest exporter of auto-parts, with a quota just over 10 per cent of the total geographic distribution somewhat biased towards developing countries and centrally planned economies. The balance of trade has improved with regard to the area outside the Common Market but has continued to deteriorate within it. This is a result of more exports of lower quality items and increased imports of relatively sophisticated parts. It is significant that 80 per cent of the imports originate from the Federal Republic of Germany, France and the United Kingdom, while only 37 per cent of total exports goes to these countries. The relatively unsophisticated nature of Italian exports is also reflected in the high proportion of replacement parts: exports account for about 15 per cent of total sales of original parts but twice that in the case of replacement parts. The original parts are mostly supplied by large firms. FIAT acquires about 90 per cent of its required raw materials, finished and semi-finished parts and components from Italian suppliers.

Since the second half of 1980 the auto-parts sector has been undergoing a process of considerable restructuring and rationalization. The automobile is becoming a highly integrated system of parts and components, each of which must be rigorously adapted to the others in its design. As a result an increasing degree of collaboration and co-ordination is required between assemblers and parts-makers not only in production but in designing and development of new models. This, in turn, requires a greater research and development capacity on the part of parts-makers, particularly those producing items most subject to innovation, such as electronic components. In this connection, it is interesting to note that FIAT has eliminated 350 out of 1200 suppliers since 1981 because they did not meet its needs. A similar process of selective elimination has been going on in the replacement parts market as well.

2 THE CASE OF FIAT

During the ‘autunno caldo (hot autumn)’ year of 1969, work organization (especially on assembly lines) and the hierarchical structure of firms were targets of radical criticisms in industrial disputes. In FIAT, formal as well as informal work organization had to be changed according to the trade union agreements of 1969, 1971, 1975 and 1977. The speed of the assembly line was reduced and a search for a new organizational model began to gain momentum. The result was a remarkable decline in labour productivity. Between 1979 and 1984, however, FIAT cut its labour force by almost 35 per
Table 4: Employment and production in FIAT auto in Italy (1976–1983)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Total no. of employees registered</td>
<td>123,500</td>
<td>121,000</td>
<td>130,000</td>
<td>137,708</td>
<td>133,424</td>
<td>118,123</td>
<td>107,655</td>
<td>97,091</td>
<td>88,722</td>
</tr>
<tr>
<td>Index (1979 = 100)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>(100)</td>
<td>(96.88)</td>
<td>(85.77)</td>
<td>(78.17)</td>
<td>(70.50)</td>
<td>(64.42)</td>
</tr>
<tr>
<td>(ii) Complete lay-off ('extraordinary' CIG*)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>20,952</td>
<td>18,594</td>
<td>18,501</td>
<td>14,569</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>(iii) Actual workers</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>137,708</td>
<td>114,830</td>
<td>99,529</td>
<td>89,154</td>
<td>82,522</td>
<td>78,722</td>
</tr>
<tr>
<td>Index (1979 = 100)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>(100)</td>
<td>(83.38)</td>
<td>(72.27)</td>
<td>(64.74)</td>
<td>(59.92)</td>
<td>(57.16)</td>
</tr>
<tr>
<td>(iv) Partial lay-off ('Ordinary' CIG*)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>16,521</td>
<td>11,322</td>
<td>10,067</td>
<td>9,446</td>
<td></td>
</tr>
<tr>
<td>(v) Employees in activity</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>137,708</td>
<td>114,830</td>
<td>83,008</td>
<td>77,832</td>
<td>72,455</td>
<td>69,276</td>
</tr>
<tr>
<td>Index (1979 = 100)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>(100)</td>
<td>(83.38)</td>
<td>(60.27)</td>
<td>(56.51)</td>
<td>(52.61)</td>
<td>(50.30)</td>
</tr>
<tr>
<td><strong>Production</strong> ('000 units of vehicles)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(vi)</td>
<td>1,325.1</td>
<td>1,275.5</td>
<td>1,323.4</td>
<td>1,307.8</td>
<td>1,275.5</td>
<td>1,118.5</td>
<td>1,131.5</td>
<td>1,222.9</td>
<td>1,267.3</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(vii) (vi)/(i)</td>
<td>10.7</td>
<td>10.5</td>
<td>10.2</td>
<td>9.5</td>
<td>9.6</td>
<td>9.5</td>
<td>10.5</td>
<td>12.5</td>
<td>14.3</td>
</tr>
<tr>
<td>(viii) (vi)/(v)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>9.5</td>
<td>11.1</td>
<td>13.5</td>
<td>14.5</td>
<td>16.7</td>
<td>18.3</td>
</tr>
<tr>
<td>(ix) Output per direct blue-collar worker</td>
<td>16.8</td>
<td>15.5</td>
<td>16.3</td>
<td>14.9</td>
<td>16.5</td>
<td>19.9</td>
<td>21.8</td>
<td>23.9</td>
<td>—</td>
</tr>
</tbody>
</table>

*a*For a definition of CIG, see note 8.  
*b*Number of cars produced per direct blue-collar worker, as reported as such by FIAT. According to this source, the figures for 1972–1975 were 19.7, 18.8, 16.9 and 14.8. The corresponding annual production figures were 1577.7, 1626.3, 1445.8, and 1180.9. In 1976 FIAT underwent structural change of its internal organization as a group.  
From FIAT.
cent, and the number of active employees halved between 1979 and 1984. This permitted a continuous increase in labour productivity throughout the period, despite the decline in its automobile production (Table 4). To what extent did microelectronics-based new technology contribute to this achievement?

(i) Flexible automation

The timing of introduction of robots is largely determined by the timing of model changes and by the expected life and production volume of the new model. The RITMO engine, for instance, was crucial in FIAT's flexible automation programme. Since it is also used, with certain modifications, for other models (Lancia's DELTA and PRISMA, and FIAT's REGATA), the life of this engine is going to be long. Thus the introduction of RITMO justified the radical modification of the existing body and motor-head assembly lines. 'Flexible automation' was introduced by FIAT in the following steps:

1972  Welding robots for FIAT 132;
1975  Welding robots for FIAT 131;
1976  Digitron system for automatic screwing of mechanical components to FIAT 131 body;
1976  Robots for underbody silencer;
1977  Robots for trim painting;
1978  Robogate welding system for RITMO;
1979  Robogate welding system for PANDA;
1981  LAM (Engine Assembly Asynchronous Line) for RITMO engine assembly;
1982  Welding robots for UNO;
1982  Assembly robots for UNO rear axle;
1982  Assembly robots for RITMO cylinder heads;
1982  Assembly robots for UNO steering box;
1984  Assembly robots for FIAT–Peugeot chassis and motor head.

The total number of robots installed by FIAT rose from 400 in 1981 to 623 in 1982, 765 in 1983 and 808 in 1984 (Table 5). In 1982, about 220 robots were installed for the UNO production only. The total is expected to grow to 954 in 1985. The main areas of robotization continue to be bodywork, but the emphasis is shifting from welding to painting and final assembly. The assembly of the new FIAT–Peugeot engine is totally robotized.

In the 1970s, FIAT's investment in robots was intended to secure flexibility in production facilities and improve conditions of work, thus meeting the trade union's demand for a new work system. This was particularly the case with welding robots. Since 1980, flexibility and labour saving have become the main objectives of robotization. Improvement in the conditions of work has become a secondary objective.
As shown in Table 6, however, the purpose of robotization varies depending on the production process. Labour saving is the primary objective in final assembly, spot welding, plastic and rubber moulding, machining and some other processes. Safety and health is the main consideration in arc welding, stamping and painting. So is quality control in machining and testing.

The most interesting case of flexible automation is the robogate welding system introduced at Rivalta and Cassino in 1978 for the RITMO model. It consists of three main elements: welding robots, self-propelling trucks moving along magnetic tracks under computerized control and a computer for programming the sequence of operations, distributing resources, starting operations and verifying them. The basic characteristic of the robogate is its high degree of flexibility: it can work on different types of cars at any time and with different equipment. In fact, every robot memorises the work programmes related to the different models of body that enter the station. This system affects employment at two different levels. Quantitatively, it has meant a reduction of blue-collar workers by about 45 per cent, from approximately 247 to 137; qualitatively, the occupational composition of the workers has changed radically (Table 7). Direct production blue-collar workers have largely disappeared, as a result of replacement by plant maintenance workers and controlling (general service) workers.

Another noteworthy innovation relates to the Engine Assembly Asynchronous Line (LAM), which is Fiat's most advanced answer to the trade unions' demand for a new work organization. On the conventional engine assembly line, the engine passes by the workers (work stations). The workers pick up parts from conveyors (heavy and bulky parts like pistons, shafts, etc.) or from bins located beside the line (small parts). The assembly is done with fixed or mobile tools. As the line moves, each worker has a certain fixed time available for carrying out his task. Productivity is determined by the line speed, and increases as the time available for each worker for his task.

<table>
<thead>
<tr>
<th>Operation</th>
<th>1982</th>
<th>1984</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Painting</td>
<td>36</td>
<td>5.8</td>
<td>100</td>
</tr>
<tr>
<td>Welding</td>
<td>452</td>
<td>72.5</td>
<td>522</td>
</tr>
<tr>
<td>Assembly</td>
<td>112</td>
<td>18.0</td>
<td>159</td>
</tr>
<tr>
<td>Others</td>
<td>23</td>
<td>3.7</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>623</td>
<td>100.0</td>
<td>808</td>
</tr>
</tbody>
</table>

*As defined by the Robot Institute of America. The 'manipulator' and 'fixed sequence' categories are not included.

From FIAT.
Table 6: Purposes of robotization at FIAT plants

<table>
<thead>
<tr>
<th>Process</th>
<th>Order of importance</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc welding</td>
<td>Flexibility</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety, health, work</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td></td>
<td></td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regular quality of work</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Assembly</td>
<td>Labour saving</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Higher quality</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Spot welding</td>
<td>Flexibility</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Safety, health, work</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>environment</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Higher quality</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic and rubber</td>
<td>Labour saving</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>moulding</td>
<td>Safety, health, work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>environment</td>
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</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Machining</td>
<td>Flexibility</td>
<td></td>
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<tr>
<td></td>
<td>Labour saving</td>
<td></td>
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<td></td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td>Regular quality</td>
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<tr>
<td>Stamping</td>
<td>Safety, health, work</td>
<td></td>
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<tr>
<td></td>
<td>environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regular quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection, testing</td>
<td>Labour saving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regular quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painting</td>
<td>Safety, health, work</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>environment</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Labour saving</td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Other</td>
<td>Labour saving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety, health, work</td>
<td></td>
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<td></td>
<td>environment</td>
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<td>✗</td>
</tr>
<tr>
<td></td>
<td>Regular quality</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

From authors' survey.

Table 7: Changes in the occupational composition of workers on the welding lines (% of total blue-collar workers)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Direct production workers</th>
<th>Supervision</th>
<th>Maintenance</th>
<th>General services</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous system</td>
<td>70</td>
<td>9</td>
<td>17</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Robogate</td>
<td>10</td>
<td>12</td>
<td>71.5</td>
<td>6.5</td>
<td>100</td>
</tr>
</tbody>
</table>

From Medusa (1983a).
decreases. In contrast, the LAM consists of a series of ten manual working groups with fixed work stations and of four automatic assembly transfer lines connected with one another by interoperative stores. The stores enable workers to organize their working and resting times individually without affecting the production flow or the total production volume. Self-propelled ‘mini-trailers’ move the engine block as well as shelves of parts. They are controlled by a number of peripheral computers monitored by a central one, which regulates the stock of parts as well as the input and output material flow from the stores and from the work stations. A working group is potentially made up of twelve blue-collar workers. Two assembly benches and a store of small parts are available for each of them. When the operator has completed the assembly on either of the benches (and before going to the other assembly bench that is already set up), he informs the system by pressing a button. A mini-trailer will then automatically pick up the assembled unit and deliver another one to be done. The operator can direct the assembled engine to the revision area if he suspects it to be defective. This system allows a remarkable operational flexibility (about 100 different versions of the RITMO basic motor) but is still a labour-intensive technology without the introduction of robots.

The introduction of the LAM has cut the labour force by 25 per cent, from 400 to about 300. The proportion of direct blue-collar workers fell from 91.5 per cent to 81 per cent. Conditions of work have improved. Not only has the work-cycle time extended by more than six minutes on the average, but sequential rigidity, heavy work and noise have been eliminated.

Currently, innovations are sometimes aimed at the total automation of assembly work. The earliest example is the UNO steering-box assembly line which went into operation in 1982. Keeping the level of production constant, robotization eliminated 29 direct blue-collar workers on this line, leaving only two indirect workers. Another example of a labour-saving innovation is the cylinder-head assembly plant for RITMO which started operation in September 1983. The main feature of this plant is the fourteen robots that carry out almost all the work that used to be done manually. The number of direct blue-collar workers was cut from 30 to only three per shift, who assemble the upper and lower cylinder heads. In general, direct employment on the line fell from 60 workers on two shifts for a production of about 1000 heads per day to nine workers on three shifts for a production of about 1900 heads per day. Output per direct worker grew from 16.6 to 211, almost a thirteen-fold increase. The number of indirect workers has increased only marginally from ten to twelve.

The latest innovation in assembly is related to the FIAT/Peugeot engine (FIRE 1000) assembly line which is being built at the Termoli factory. This is an additional line to the existing plants and has thus required new employment. The plant has two lines. Its cylinder-head assembly line is similar to that for RITMO, but the simplified design of the cylinder head (a single piece) has further cut the number of direct blue-collar workers from three to two. For
the engine assembly, 93 robots have been introduced. Only 85 direct workers are required for a daily production of about 2100 engines, as compared with about 300 workers on the LAM line for a production of about 1600 engines. Thus, output per worker grew from 5.33 to 24.70, or by 4.63 times.

It should be noted, however, that flexible automation does not replace fixed automation completely. In producing large series, the latter technology still has a wide area of application, and its labour-saving effect is much greater than that of robots. This may be illustrated with reference to spot welding. The automation rate at FIAT plants rose from 19 per cent in 1972 (ARGENTA) to 50 per cent in 1974 (FIAT 131), 61 per cent in 1978 (RITMO) and 99 per cent in 1982 (UNO). The proportion of spots welded by robots was only 6, 12, 28 and 36 per cent, respectively. What is even more important is that a number of other changes have created far greater employment impacts on the Italian automobile industry than robotization, as will be made clear in the following sections.

(ii) Rationalization of design and work organization

The use of computers makes it possible to simulate the behaviour of the different auto components and thereby optimize the structure and shapes of components. One of the results is a reduction of the number of body components to be assembled. For example, the number of sheet-metal pieces to be assembled for UNO is only 172, as compared with 267 pieces for FIAT 127. The number of welding spots fell from 3800 to 2700. The overall result is a reduction in time worked per vehicle, which is 40 per cent shorter for UNO than for RITMO. Moreover, some models, like PANDA and UNO, have been designed without the conventional partition in the side window, doing away with a triangular window which opens sideways rather than downwards. This eliminated a labour-intensive operation.

Second, efforts have been made towards a greater standardization of components. FIAT is trying to reduce the model-specific components by 25 per cent before the end of 1985.

Third, the number of operations to be carried out along the assembly line has been reduced by increased use of subassembly systems. A good example is the UNO front suspension integrated with the steering box. This permits a higher degree of automation and a greater use of subcontractors. It can also eliminate certain work items. The most outstanding example is the closure of the historic Lingotto Factory in Turin where 8000 blue collar workers were employed in July 1981. Some work items have been transferred to other FIAT plants: the bodywork of Lancia Delta to Chivasso, the bodywork for the FIAT 238 van, which was replaced by DUCATO, to the new SEVEL factory (FIAT/Peugeot) near Chieti, and small press works to Mirafiori and Rivalta. Others have been subcontracted: for example, the X1/9 and 124 SPYDER sport cars and the multi-purpose CAMPAGNOLA are now assembled by two body-makers, Bertone and Pininfarina; radiators are now
produced by Ipra and Valeo Sus; the metallic structure of the seats is now supplied by a number of specialized companies. As a consequence, most of the Lingotto workers have been put on *Cassa Integrazione Guadagni* (CIG) at zero hours (or 'extraordinary' CIG).  

(iii) Industrial relations

In 1980 a radical change took place in FIAT's policy. With a view to regaining international competitiveness, the company began to dismiss employees as a means to cut costs. In September FIAT declared a surplus of 24,000 blue-collar workers. After a 35-day fight with the trade unions, an agreement was signed on 18 October to put 23,000 workers on extraordinary CIG (i.e. complete lay-off). At the same time FIAT introduced a financial incentive for voluntary resignation. In total, 33,535 workers left the company between October 1980 and October 1983, 77 per cent of them voluntarily (Table 8).

The 'official' employment at FIAT dropped by about 30 per cent between 1979 and 1983. If we include the workers on extraordinary CIG, most of whom are very unlikely to go back to the factory, FIAT's labour force shrank by 40 per cent. The average number of workers actually at work in 1983 was only 52.6 per cent of the 1979 level, resulting in a remarkable improvement in productivity (Table 4).

FIAT's hard line in personnel policy and the wide use of the ordinary and extraordinary CIG (i.e. partial and complete lay-off) also reduced absenteeism by 60 per cent between 1979 and 1983. The CIGs tend to reduce absenteeism for two reasons. First, the more often a worker takes sick leave, the more likely he is to be put on extraordinary CIG. Second, there is a high proportion of invalids and inefficient people among the workers on extraordinary CIG: more than 2000 out of 7500 blue-collar workers on a list studied were older than 40 years, 800 were invalids and a few thousand were considered to be inefficient by the company, although there was no reliable evidence.  

<table>
<thead>
<tr>
<th>Cause</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismissed</td>
<td>572</td>
<td>1.7</td>
</tr>
<tr>
<td>Resignations</td>
<td>25,845</td>
<td>77.0</td>
</tr>
<tr>
<td>Deaths</td>
<td>718</td>
<td>2.2</td>
</tr>
<tr>
<td>Injuries</td>
<td>1,989</td>
<td>5.9</td>
</tr>
<tr>
<td>Retirement</td>
<td>3,022</td>
<td>9.0</td>
</tr>
<tr>
<td>Others</td>
<td>1,389</td>
<td>4.2</td>
</tr>
<tr>
<td>Total</td>
<td>33,535</td>
<td>100</td>
</tr>
</tbody>
</table>

From trade unions.
(iv) Employment effects of robotization

The differential effects of all these changes on different groups of workers may be illustrated with reference to the case of the body-work plant at Mirafiori, Turin. During the three-year period starting in the fourth quarter of 1980, the number of workers at this plant fell from 17,600 to 12,650, or by 28 per cent. If we include those who were on extraordinary CIG, the actual workforce declined to 10,350, by 41 per cent. Direct production workers decreased by 54.2 per cent. Clearly, they have been hit harder than other groups by the rationalization. Employment declined most in welding and painting, where greater efforts at automation and particularly robotization took place since working conditions were especially poor in these areas. Absenteeism decreased by about two-thirds. Because the programmed daily production fell by only 20 per cent during the same period (from 2,240 to 1,780 vehicles), the productivity of the direct production workers effectively involved in production rose by 55 per cent. The productivity increment in welding and painting was above the average.

If one accepts that a robot replaces about 1.5 workers per shift and that the robots are used on two shifts, one obtains a replacement coefficient of three workers per robot. If this coefficient is applied to the 185 robots installed at FIAT in 1983 and 1984 (Table 5), the result is the replacement of 555 workers. Added to the previous 1,581 replaced by robots in the preceding years, this would put the redundancy caused by robotization before the end of 1984 at 2,136. In reality, the blue-collar workforce at FIAT fell from 110,049 in 1980 to 78,893 in 1983, or by 31,156. Even if we assume that all the workers replaced by robots have lost their job, they would represent only 5 per cent of the blue-collar redundancy. The replacement of blue-collar workers by robots has up to now been a minor factor in explaining the employment trend at FIAT. This conclusion appears consistent with the experience of Alfa Romeo.

3 THE CASE OF ALFA ROMEO

During the 1970s, the annual output at Alfa Romeo remained at around 200,000 vehicles and the workforce at about 42,000. However, it has been less successful in reducing costs than FIAT. Its production capacity (283,000 units) was about 100,000 units over the market potential. Its indirect/direct worker ratio was much higher than its competitors': for instance, the ratio at FIAT factories was 0.37, while it was 0.64 at Arese and 0.79 at Pomigliano. To solve the problem, on 9 March 1982, an agreement was signed between Alfa Romeo and the trade unions. It included provisions for periodic stoppage of production using ordinary CIG and for the application of CIG at zero hours for at least 5,708 workers, mainly indirect blue-collar and white-collar workers. As a result, between 1981 and 1982, production fell by 4.5 per cent and the number of workers actually employed in production—i.e. excluding
the workers on CIG at zero hours and on periodic ordinary CIG—by 29.2 per cent, permitting a productivity increase of 35 per cent. Absenteeism fell at Pomigliano from over 20 per cent in 1979 to 13–14 per cent in 1982.

Compared with the scale of the dismissal of surplus labour that has been achieved as a result of a radical change in the personnel policy, the labour-saving effect of robotization is only marginal.

In earlier years, automation and robotization advanced essentially with a view to 'renewing the product and improving the man/machine ratio by eliminating or reducing heavy, uncomfortable, or disagreeable work', particularly in forging and painting shops. Since the end of the 1970s, however, the primary objective has become cost reduction through increased flexibility: 'If one takes as 100 the overall value of the motivations that determined investment for automation and robotization in the 1978–82 period:

— 50 per cent was aimed at increasing work flexibility;
— 15 per cent was aimed at regaining product mix flexibility;
— and a mere 10 per cent was aimed at improvement of work conditions.'

In 1982, 40 robots were installed for welding the body of the new ALFA 33. This raised the total number to 81, of which 62 were for welding, ten for painting and six for foundry and forgery. The impact of this investment on employment has been remarkable: 'at Pomigliano d’Arco (Naples) body welding of the new ALFA 33 is done by 40 robots and to produce 750 bodies, 550 direct blue-collar production workers are required. At Arese (Milan) the robots have not yet been introduced and 1300 direct blue-collar workers are required for 620 bodies.'

At Pomigliano 'the welding line, in switching from ALFA SUD to (ALFA) 33, was reduced by 400 jobs: 220 due to the higher productivity of the robot line, and 180 to fewer welding spots'.

4 IMPACT OF THE NEW TECHNOLOGY ON THE AUTO-PARTS SECTOR

(i) The sample firms

To study the employment impact of product (electronic components) and process technology (electronic equipment) innovations, we examined five companies that produce electronic components and ten companies that use electronic production technology. Auto-parts accounted for 50, 75 and 95 per cent of total turnover of the mechanical, electronic and plastic parts producers, respectively.

Our sample is biased towards larger firms, because we selected those which had been using electronic technology. Our choice of product lines is based on a similar consideration. In light-alloy casting, the only firm that had been using electronics to a meaningful extent refused to cooperate for our study.

Overall, employment declined by 14 per cent between 1978 and 1983
Table 9: Employment trends at the selected component makers

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical parts (6)</td>
<td>13 390</td>
<td>13 090</td>
<td>12 835</td>
<td>11 849</td>
<td>11 250</td>
<td>10 330</td>
</tr>
<tr>
<td>Electro-mechanical/electronic parts (6)</td>
<td>7 332</td>
<td>7 638</td>
<td>7 966</td>
<td>7 360</td>
<td>7 100</td>
<td>7 330</td>
</tr>
<tr>
<td>Plastic parts (3)</td>
<td>2 718</td>
<td>2 685</td>
<td>2 450</td>
<td>2 648</td>
<td>2 604</td>
<td>2 503</td>
</tr>
<tr>
<td>Total (15)</td>
<td>23 440</td>
<td>23 413</td>
<td>23 251</td>
<td>21 857</td>
<td>20 954</td>
<td>20 163</td>
</tr>
</tbody>
</table>

*Note*
Figures in parentheses indicate number of sample firms.

(Table 9). The most remarkable fall (23 per cent) took place among the mechanical parts producers, where the demand fell more and the structural change was greater. In contrast, the producers of electronic parts maintained their employment levels, thanks to the growth of the market. To look at different occupational groups, blue-collar employment declined much more than white-collar (15.7 per cent against 5.7 per cent). It is interesting to note that employment of white-collar workers decreased only at firms producing mechanical parts (18.3 per cent), while their employment increased by 7.5 per cent and 12.23 per cent at the firms producing plastic and electronic components, respectively. Employment trends roughly correspond to those of the turnover, having risen by 22.2 and 40.4 per cent in the plastic and electronic parts sector, respectively, while the mechanical parts producers suffered from a 9 per cent decline.

In total, eighteen electronic components were produced by the six firms. Production of five items started in 1980 and ten items between 1981 and 1984. However, electronic components have replaced some of the conventional electromechanical components. For instance, an electronic control panel for air conditioning, which is built of a plastic keyboard and a printed circuit board, is a substitute for metal levers, steel cables and medium-dimensioned plastic parts. Moreover, because electronic components are less vulnerable to damage and breakdowns, the replacement parts market is reduced. Thus we need to be careful in assessing the net employment effect.

(ii) **Diffusion of microelectronic production technology**

Application of electronics in production processes can mean different things. In some cases, parameters of raw materials (temperature, density, etc.) and machinery (e.g. pressure of plastic and rubber moulds) are controlled
Table 10: Types of electronic machinery in the auto-parts sector

<table>
<thead>
<tr>
<th>Product line</th>
<th>NC metal-cutting machines</th>
<th>Forming machines&lt;sup&gt;a&lt;/sup&gt; controlled by a microprocessor</th>
<th>Electronic testing equipment</th>
<th>Robots</th>
<th>Laser</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electro-mechanical/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electronic</td>
<td>3</td>
<td>13</td>
<td>27</td>
<td>2</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Mechanical</td>
<td>64</td>
<td>200</td>
<td>4</td>
<td>11</td>
<td>18</td>
<td>—</td>
</tr>
<tr>
<td>Plastic</td>
<td>—</td>
<td>26</td>
<td>—</td>
<td>1</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>Total (percentage)</td>
<td>67</td>
<td>239</td>
<td>31</td>
<td>14</td>
<td>42</td>
<td>11</td>
</tr>
</tbody>
</table>

<sup>a</sup>Machines which do not produce metallic chips.
with electronic devices. In other cases, machines are driven and controlled completely with such devices (i.e. NC machine tools and robots). The extent and mode of application of electronics depend on the length of the production cycle and the complexity of the product to be manufactured: some firms have very few production processes and little or no assembly work, while others are engaged in a wider range of work including assembly.

Table 10 shows the types of electronic equipment used by the sample firms. In about 60 per cent of the cases, the operational parameters of the machine are controlled by a microprocessor which replaces electromechanical or oleopneumatic mechanism. NC machines (16 per cent of the total) are used almost exclusively by mechanical parts producers. The laser and the test/control equipment are mainly used by electromechanical and electronic component manufacturers. Robots are programmable up to 75 per cent.

Regarding the timing of introduction of these machines, 90 per cent of the electronic equipment was installed in 1980–83. However, there is a remarkable difference in the timing of introduction depending on the type of machine. While substantial proportions of NC metal-cutting machines and testing equipment were already installed by the second half of the 1970s (40 and 26 per cent, respectively), the other machines were introduced almost entirely in and after 1980.

NC metal-cutting machines are naturally used only in the machining and tool shops. The distribution of the robots is quite interesting: the pick-and-place robots are used slightly more in machining than assembly, while the programmable ones are almost exclusively used in assembly.

The electromechanical and electronic component producers, for whom assembly is a major process and testing is crucial, introduced electronic

Table 11: Purposes of the application of electronic equipment

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Mechanical parts</th>
<th>Electro-mechanical/electronic parts</th>
<th>Plastic parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliminating heavy and harmful work</td>
<td>80</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Improving product quality</td>
<td>145</td>
<td>205</td>
<td>180</td>
</tr>
<tr>
<td>Increasing production flexibility</td>
<td>115</td>
<td>95</td>
<td>—</td>
</tr>
<tr>
<td>Increasing productivity</td>
<td>170</td>
<td>120</td>
<td>95</td>
</tr>
<tr>
<td>Reducing labour cost</td>
<td>90</td>
<td>80</td>
<td>25</td>
</tr>
</tbody>
</table>

*Note*
Firms were asked to distribute a total score of 100 among the various reasons. The values indicated in the table are the sum of the scores for each reason.
equipment mainly for the purpose of quality control. The case with the plastic moulding firms was similar (Table 11). In contrast, the mechanical parts producers concentrated on increasing productivity and reducing the labour cost, obviously because their production processes are still quite labour-intensive.

(iii) Employment effects

Two of the electronic component manufacturers had been using electronic machines sufficiently to permit a quantitative assessment of employment effects (Table 12). Overall, the introduction of 56 electronic machines caused replacement of 60 blue-collar workers: thirteen of them were dismissed and the rest were assigned to other jobs within the same firms. As seventeen new workers were hired and as the number of indirect blue-collar workers remained almost constant, the net result was an increase in the number of workers. What is interesting is the selection of the blue-collar workers assigned to electronic machines. In total 24 workers were assigned to the work, seventeen newly recruited and seven transferred within the firm. This reflects the firms' negative assessment of the learning capacity of the existing workers.

Regarding the acquisition of knowledge required for the operation of the electronic machines, the workers at all six firms have attended internal training courses, except for a worker who attended an external course. However, the firms do not recognize any difference in occupational ability between the blue-collar workers assigned to the new type of machines and those assigned to other machines.

Table 12: Employment effect of electronic equipment on direct blue-collar workers

<table>
<thead>
<tr>
<th>Equipment</th>
<th>No. of machines</th>
<th>Replaced</th>
<th>Newly recruited</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic component producers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC forming machines</td>
<td>12</td>
<td>11</td>
<td></td>
<td>-11</td>
</tr>
<tr>
<td>Robot—Pick-and-place—Programmable</td>
<td>4</td>
<td>18</td>
<td>6</td>
<td>-12</td>
</tr>
<tr>
<td>Laser</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>-4</td>
</tr>
<tr>
<td>Testing equipment</td>
<td>23</td>
<td>25</td>
<td>9</td>
<td>-16</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>60</td>
<td>17</td>
<td>-43</td>
</tr>
<tr>
<td><strong>Mechanical parts producers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC machine tools</td>
<td>21</td>
<td>15</td>
<td>1</td>
<td>-14</td>
</tr>
<tr>
<td>Robot—Pick-and-place—Programmable</td>
<td>11</td>
<td>15</td>
<td>1</td>
<td>-14</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
<td>3</td>
<td></td>
<td>-3</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>-50</td>
<td>+2</td>
<td>-48</td>
</tr>
</tbody>
</table>
Among the mechanical parts producers, the use of electronic machinery in metal forming (i.e. stamping and forging) is limited. Its employment impact is negligible. The situation is different at the firms producing components such as silencers, clutches and carburettors. In these firms, electronic equipment reduced the number of workers by 48 (Table 12), which was equal to 5.7 per cent of the total blue-collar workers (840) who left the companies between 1978 and 1983. Out of the 48, eleven (22.9 per cent) resigned and the others were transferred to other jobs within the firms.

Unlike the electromechanical and electronic component producers, these firms assigned existing employees to the new machines after providing them with courses.

The application of microprocessors for controlling raw material inputs and plastic moulding machines does not replace manual operations but improves product quality and reduces the rejection rate. Thus there are no significant employment effects. Some training courses have been organized for the maintenance staff and technicians by the plastic moulding firms.

5 SUMMARY AND CONCLUSIONS

In the 1950s and 1960s many favourable factors contributed to a rapid and continuous increase in labour productivity. Production increased very fast, and firms made huge investments in highly specialized machinery to benefit from the economies of larger-scale production. Work organization was improved enormously by the introduction of transfer machines, and trade unions did not object to this Tayloman organization of work. Those two decades were a period of growth without serious constraints.

The situation changed completely after 1973. The domestic demand for automobiles was depressed. The trade unions became more critical of the existing work organization and rationalization and managed to maintain the employment level in spite of the declining production level, causing serious overmanning of the industry. The productivity of labour fell rapidly and the international competitiveness of the industry was lost. Thus, the period between 1973 and 1980 was one of serious crisis for FIAT and Alfa Romeo.17

Against this background, the introduction of microelectronic technologies was initially stimulated by the trade unions' demand for the elimination of tiring and unhealthy working conditions. It primarily affected machining plants, while the assembly plants were only marginally involved. Experiments in this initial period, however, served as pilot projects for the restructuring of plants during the 1980s, which is aimed at flexible automation and not so much at the improvement of working conditions.

While in the 1960s the negative employment impact of transfer machines was more than offset by the rapid expansion of the market for automobiles, in the late 1970s and 1980s flexible automation based on microelectronics was introduced in the context of a stagnant market situation. Moreover, the increased international competition has induced major efforts to rationalize work organization. This was intended to eliminate surplus labour, which had
grown as a result of the overmanning of the industry in the 1970s. After 1980, companies successfully eliminated surplus labour, as the bargaining power of the trade unions declined as a result of deterioration of the labour market situation. Labour-saving efforts have also been made in other areas, for example by means of simplification of vehicle designs and reduction of the number of parts and components to be assembled. The loss of job opportunities caused by microelectronic technologies has been marginal compared with the total number of jobs lost for all these reasons. The negative employment effect of flexible automation has also been limited because it was sometimes introduced as a substitute for more labour-saving special-purpose automatic machines.

Both labour productivity and the level of production have a crucial influence on the level of employment, but they are not independent. Whereas in the past the causal relation started mainly from the latter, today the direction has been reversed as a result of the intensification of international competition. To survive, improvement in productivity is essential. FIAT is now becoming one of the most intensive robot users among the European automobile manufacturers. In contrast, labour-saving investment has been limited in the case of Alfa Romeo, which seems to be trying to increase productivity by means of further rationalization of work organization, at least in the short run. Auto-parts producers are making similar efforts. Since no major jump in automobile production is foreseeable in the near future, employment is likely to fall, although not as fast as in the early 1980s, when long-delayed rationalization measures took place.

The major impact of new technologies on employment will come when they are introduced in the assembly lines, where a large number of workers are employed. The most recent application of robots on engine assembly lines suggests that a new concept of robotization is developing, which could have huge negative effects on employment unless automobile production increases rapidly. So far, those who have lost their jobs have been supported by the government fund of the CIG. It is, however, questionable whether the Government will be able to endure the heavy financial burden for long. Clearly new job opportunities need to be created elsewhere.

ACKNOWLEDGEMENTS

The authors would like to thank Ing. Uberto and Dr Cerato of FIAT and Ing. Borella of Alfa Romeo for their stimulating discussions and useful suggestions.

NOTES

1 In this study, ‘FIAT’ refers to the FIAT auto group, which includes FIAT, Lancia, Autobianchi and Ferrari unless specified otherwise.
Robots, Employment and Industrial Relations in the Italian Automobile Industry

2 Enrietti (1982).
3 Pellegrini (1982).
5 The robogate has been installed in places other than FIAT. For example, an up-dated version of robogate is being introduced in General Motors’ seven assembly plants (Automotive News, 6 February 1984).
6 Quaderni di industria e sindacato, No. 6, Jan.–Mar. 1981.
8 Cassa Integrazione Guadagni (CIG) is a contractual practice in the Italian employment system whereby workers laid off are paid about 80–90 per cent of their wages by the Government, not by the firm. CIG can be either ‘extraordinary’ (or ‘at zero hours’), which is complete lay-off, or ‘ordinary’, which is partial lay-off.
10 Cf FLM (1983).
13 As note 12, pp. 28–29.
16 Five firms had over 1000 workers; four between 500 and 999; one between 250–499; four between 100 and 249; and only one fewer than 100.
17 Silva, Grillo and Prati (1982).

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ANFIA: L’Auto in Cifre (Turin), various years.


Robots, Employment and Industrial Relations in the Italian Automobile Industry

Quaderni di industria e sindacato: 'Le prospettiva robotica (The robotic perspective)' (Rome), No. 6, 1981.
CHAPTER VII

Microelectronics and the Internationalization of the Brazilian Automobile Industry

José Ricardo Tauile

The main objective of this study is to assess the impact of microelectronic technologies—numerically controlled (NC) machine tools, robots and programmable controllers—on employment, work and industrial organization in the Brazilian automobile industry, including both the final assembly of cars and trucks and the auto-parts manufacturing.

Section 1 contains a brief review of the development of this industry, providing the background for our analysis. It will be argued that the increasing integration of the world's automobile industry influences the technological development of the Brazilian automobile industry through the exchange of parts and components. Section 2 is concerned with the extent and pattern of diffusion of microelectronic equipment in the assembly sector of the industry and its relationship with the structure of the industry. It will be pointed out that local economic conditions and multinational automobile companies' strategies have been influencing the diffusion of new technologies in this industry. Section 3 deals with the auto-parts manufacturing sector where the new technology is spreading, partly as a response to assemblers' policies. Section 4 will examine the impact of microelectronic equipment on employment, work organization and industrial relations.¹

Our study was considerably constrained by the paucity of statistical data on the new technology. Adequate data were not available from government or trade union publications, and information provided by firms was not systematic. At the time of writing (early 1984), the Brazilian economy was in a serious crisis. One of the most severe social effects of this crisis was the high level of both unemployment and underemployment. The relationship between automation and unemployment was an extremely delicate issue and firms were wary of discussing it. The major metalworkers' union in the industry (in São Bernardo do Campo, São Paulo) had been under federal intervention since the first half of 1983, which made it even more difficult to gain access to relevant data. To reduce this information gap and assist it in policy-making, the Special Secretariat for Informatics (SEI), which is linked to the National Security
Council, formed a Special Commission on Manufacturing Automation (CEAM) in 1983. It was composed of representatives of the community at large who were concerned with the matter. Three different subcommittees were set up to study technological issues, industrial and market aspects and socioeconomic impacts. The final reports of these subcommittees were presented at the First National Congress on Industrial Automation (CONAI), held in São Paulo in July 1983. Some of the information contained in those reports, which may be regarded as the most up-to-date published data from official sources so far, was useful for our study.

1 GENERAL BACKGROUND OF THE INDUSTRY

Before 1950, automobile production in Brazil was confined to the assembly of vehicles imported in the completely knocked-down (CKD) form. Auto-parts producers showed little vitality, except when the supply of imported parts was cut off (e.g., during the Second World War). They worked almost exclusively for the replacement parts market, using rather rudimentary production techniques.

From the beginning of the 1950s onwards, however, a series of policy measures were taken by the Government to establish a local automobile manufacturing industry. In 1952, the Federal Government created, through its Industrial Development Commission (CDI), the 'Subcommittee on Jeeps, Tractors, Trucks and Cars'. One of the Subcommittee's first acts was to ban the importation of auto-parts that were produced in the country. In 1953, a new act prohibited the import of fully assembled motor vehicles. Other measures followed, such as tariff exemption for the import of machine tools, which induced entrepreneurs to invest in the auto-parts sector. A survey conducted by the National Syndicate of the Industry of Automotive Vehicle Components discovered that out of the 678 firms surveyed in the sector, 159 had established themselves between 1951 and 1955.

During the same period, Willys-Overland came to Brazil to produce jeeps. So did Volkswagen, who wanted to produce cars and vans. But it was only in the second half of the decade, after the creation of the Executive Group of the Automobile Industry (GEIA) in 1956, that the industry really began to develop. In that year GEIA approved seventeen projects, out of which twelve were implemented.

The entry of North American firms into the Brazilian market was slow at the beginning. GM and Ford produced only trucks, while Chrysler entered indirectly through its minority shareholding in the French Simca (Willys-Overland also had a minor participation in Willys do Brasil). It was European firms such as Volkswagen and Daimler-Benz that took the lead in the production of cars and trucks, respectively. Auto Union was only a Vemag licenser.

After 1955, the Government permitted importation of used machines to promote industrialization. This was very important for the establishment of
the Brazilian automobile industry, which began by producing obsolete models that were often out of production elsewhere, using old production methods. The Government’s support to the automobile industry was not restricted to the provision of such direct incentives. During the Kubitschek years (1955–1961), for example, the Brazilian highway network was extended by 40 000 km.

From 1957 to 1962, production increased more than sixfold, from 30 541 to 191 194 units, to satisfy the demand that had been suppressed as a result of the import restriction since the beginning of the 1950s. This period was also characterized by the appearance of a large number of auto-parts manufacturers. A significant portion of them was owned by foreign capital. ‘In some cases the decision of foreign-owned auto-parts producers to invest was spontaneous, stimulated by an expanding market for their products. In other instances, however, the investment was a result of direct pressures exerted by assembler firms which, compelled to meet certain indices of nationalization, attempted to guarantee the supply of parts and components’. By 30 June 1962, the level of the local content had reached 86.4–94.3 per cent, depending on the type of vehicle. After 1963, the industry continued to grow, but at a slower pace. Automobile production in Brazil fell to 183 707 units in 1964, but then increased again until reaching 224 609 units in 1966. During the first growth cycle, production was not very diversified. By 1967, 51 different models had been introduced, of which 21 were put on the market in 1966 and 1967. In the next ten years, 139 new models came onto the market.

The second phase of accelerated growth was 1968–74, after which date the growth rate slowed down. Product diversification increased to meet the demand in the upper income market. The market for used cars also showed some growth. Ford and General Motors started to manufacture cars, and Chrysler began to invest in car production. Competition intensified and some assemblers were absorbed by others: Willys by Ford, Vemag by Volkswagen, Simca by Chrysler and Fábrica Nacional de Motores (FNM) by Alfa Romeo. This wave of takeovers eliminated the two major national producers—Vemag and FNM.

Production technology was still not up to international standards as part of the investment during this period was intended for the importation of used machinery from abroad. Between 1966 and 1974, however, the output per worker doubled in the assembly sector (Table 1). This increase in productivity may be explained ‘... by several factors—improved machinery, change in the relation between the number of production workers and indirect labour employed, etc.—but there seemed to be a lot of pressure on the workers to intensify their effort at work. By the time of the interviews ... a reduction of production was accompanied by a drive to increase profits. There were lots of pressures to increase production per worker without changing the techniques of production.’ In 1974, the real wage in the industry was at the same level as in 1966, after having increased by 17 per cent in 1972.

After 1974, despite the slowdown of the growth rate of the industry and the
Table 1: Production, employment and exports in the Brazilian automobile assembly industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (000 units)</th>
<th>Annual average no. of employees (000 workers)</th>
<th>(1)/(2)</th>
<th>Exports (000 units)</th>
<th>% of exports in production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>225</td>
<td>51</td>
<td>4.4 (100)</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>1967</td>
<td>225</td>
<td>49</td>
<td>4.6 (105)</td>
<td></td>
<td>3.2</td>
</tr>
<tr>
<td>1968</td>
<td>280</td>
<td>55</td>
<td>5.1 (116)</td>
<td></td>
<td>7.1</td>
</tr>
<tr>
<td>1969</td>
<td>354</td>
<td>64</td>
<td>5.6 (127)</td>
<td></td>
<td>7.7</td>
</tr>
<tr>
<td>1970</td>
<td>416</td>
<td>64</td>
<td>6.5 (148)</td>
<td></td>
<td>8.1</td>
</tr>
<tr>
<td>1971</td>
<td>516</td>
<td>70</td>
<td>7.3 (166)</td>
<td></td>
<td>7.6</td>
</tr>
<tr>
<td>1972</td>
<td>622</td>
<td>75</td>
<td>8.2 (186)</td>
<td>13</td>
<td>2.1</td>
</tr>
<tr>
<td>1973</td>
<td>750</td>
<td>89</td>
<td>8.5 (193)</td>
<td>24</td>
<td>3.2</td>
</tr>
<tr>
<td>1974</td>
<td>905</td>
<td>104</td>
<td>8.7 (198)</td>
<td>64</td>
<td>7.1</td>
</tr>
<tr>
<td>1975</td>
<td>930</td>
<td>104</td>
<td>8.9 (202)</td>
<td>72</td>
<td>7.7</td>
</tr>
<tr>
<td>1976</td>
<td>986</td>
<td>107</td>
<td>9.3 (211)</td>
<td>80</td>
<td>8.1</td>
</tr>
<tr>
<td>1977</td>
<td>921</td>
<td>112</td>
<td>8.3 (189)</td>
<td>70</td>
<td>7.6</td>
</tr>
<tr>
<td>1978</td>
<td>1064</td>
<td>116</td>
<td>9.2 (209)</td>
<td>96</td>
<td>9.0</td>
</tr>
<tr>
<td>1979</td>
<td>1127</td>
<td>125</td>
<td>9.0 (205)</td>
<td>105</td>
<td>9.3</td>
</tr>
<tr>
<td>1980</td>
<td>1165</td>
<td>130</td>
<td>8.9 (202)</td>
<td>157</td>
<td>13.5</td>
</tr>
<tr>
<td>1981</td>
<td>781</td>
<td>116</td>
<td>6.7 (152)</td>
<td>212</td>
<td>27.1</td>
</tr>
<tr>
<td>1982</td>
<td>859</td>
<td>106</td>
<td>8.1 (184)</td>
<td>173</td>
<td>20.1</td>
</tr>
<tr>
<td>1983</td>
<td>896</td>
<td>104</td>
<td>8.7 (198)</td>
<td>169</td>
<td>18.9</td>
</tr>
<tr>
<td>1984</td>
<td>864</td>
<td>102</td>
<td>8.5 (193)</td>
<td>196</td>
<td>22.7</td>
</tr>
</tbody>
</table>

*Includes cars, vans and utility vehicles, as well as small trucks, trucks and buses. During the period under consideration, there was no CKD assembly in Brazil.

^Figures in parentheses indicate indices (1966 = 100).

From ANFAVEA.

opposition of already existing firms, FIAT and Volvo started their production in Brazil. FIAT received strong support from the State of Minas Gerais, which participated in the investment. FIAT also entered the truck market by acquiring Alfa Romeo and using its production facilities in the state of Rio de Janeiro. Volvo specialized in the production of trucks and buses. Both companies used advanced technologies of that period, such as transfer machines designed for the production of one basic model. The last big takeover in the Brazilian automobile industry occurred in 1980, when Chrysler was absorbed by Volkswagen.

Until 1980, automobile production kept growing fairly steadily except for 1977, although more slowly towards the end of the period (Table 1). The crisis of the Brazilian economy which was triggered off, among other factors, by the second oil crisis in late 1979–80 hit the industry very hard. The extremely high interest rate on consumers' loans discouraged the purchase of cars: '... the cheaper loan to buy a (brand new) car (in 24 months) costs
(currently) 150 per cent per annum, or—something to feature in a book of records—the equivalent of more than five cars at every two years of installments. The Government's restriction on oil consumption had a similar effect. The production level in 1984, although higher than those of 1981 and 1982, was still lower than the level reached between 1974 and 1980. This brought about very serious employment problems (Table 2). The production of buses and trucks was recovering slightly at the time of writing.

Export of automobiles has been stimulated by the creation, in 1972, of BEFIEX (Banco do Brasil's Commission for the Concession of Fiscal Benefits and Special Export Programmes), which aimed at promoting the growth of Brazilian exports and reducing the dependency of foreign subsidiaries on their principal companies regarding export policy. These BEFIEX programmes allowed the firms who committed themselves to making certain volume of exports to benefit from a series of concessions, such as exemption from import duties and from taxation on imports of industrialized products linked to export activities. These imports were not subject to the similarity clause—concerning capital goods and raw materials—but were limited by a specific percentage of the value of exports. Forty per cent (in terms of value) of all export deals handled by BEFIEX up to 1981 were related to the automobile industry. As shown in Table 1, exports rose to nearly 30 per cent of the automobile production in 1981. In 1971 this industry exported to sixteen countries (two countries receiving 63 per cent of total exports), and in 1980 to 77 countries (three of them receiving 51 per cent of total exports).

However, Brazil's automobile exports have been facing increasing obstacles, the major ones being the economic crisis in importing countries and

<table>
<thead>
<tr>
<th>Year</th>
<th>Assembly (A)</th>
<th>Auto-parts (B)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>104</td>
<td>200</td>
<td>304</td>
</tr>
<tr>
<td>1975</td>
<td>105</td>
<td>230</td>
<td>335</td>
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<td>1976</td>
<td>112</td>
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<td>338</td>
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<td>1977</td>
<td>113</td>
<td>235</td>
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<tr>
<td>1978</td>
<td>119</td>
<td>270</td>
<td>389</td>
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<tr>
<td>1979</td>
<td>128</td>
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<tr>
<td>1980</td>
<td>133</td>
<td>279</td>
<td>412</td>
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<tr>
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<td>1982</td>
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<td>1983</td>
<td>101</td>
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<td>316</td>
</tr>
<tr>
<td>1984</td>
<td>106</td>
<td>240</td>
<td>346</td>
</tr>
</tbody>
</table>

*The figures in column B differ somewhat from the corresponding figures in Table 1, which are the annual average.

(A) from SINDIPECAS and (B) from ANFAVEA.
strong competition posed by Japanese cars, which account for an increasing share of the imports by Third World countries (even in Latin American countries such as Argentina, Uruguay and Chile, the Japanese share in car imports has been growing). Some assemblers in Brazil have been trying to cope with this by exporting CKD vehicles, in order not to lose economies of larger-scale production.

Concerning other recent international trends, two assemblers in Brazil have released so-called ‘world cars’ (a concept which may not be very precise or new; one assembler’s representative said that they had been producing world cars since the 1930s). General Motors introduced Monza (Ascona) in 1982 and Ford Escort in 1983. Volkswagen followed suit with Santana and FIAT with Uno, both in 1984. A greater degree of exchange of parts and components may be expected among several production branches of the same corporations scattered around the world, but exactly how far this will go seems to depend largely on the flexibility of their host countries in policies regarding import of parts and components.

Such global strategy of multinationals has had some adverse effects on the Brazilian automobile industry, since certain parts of the vehicles are now systematically imported. This naturally constrains the development of the local manufacturing capacity in the related lines of production. In fact, the export-oriented government policy in the last ten years has allowed assemblers to reduce the local content of their cars to about 85 per cent. The programmes of ‘world cars’ are supposed to reduce the local content even further, down to 75 per cent, and this has, of course, been a great threat to the auto-parts sector as will be discussed below.

On the whole, however, all assemblers enjoy substantially positive balances of trade; the value of their imports has been far lower than that of their exports of parts and vehicles. This suggests that by and large the export-oriented policy tends to work in favour of the Brazilian economy and that there are some grounds on which to support the introduction of new technologies including imported equipment, even though the overall policy remains to restrict imports with a view to reducing the foreign debt and protecting the local production of similar equipment.

2 ASSEMBLERS AND NEW TECHNOLOGIES

For the Brazilian automobile industry the early 1980s seem to have been a transition period in which competition has intensified. Three different but highly interrelated factors are causing significant changes in the industry’s organization and production methods:

(a) the shrinking domestic market after 1980 (Table 1) and the extremely serious crisis that has since been affecting the Brazilian economy as a whole (in particular, the growing foreign debt);
(b) the intensification of competition in the world market for automobiles
and the consequent restructuring of the industry at the international level, which was encouraged by the use of new microelectronic technologies; and

c) the availability of locally produced microelectronic equipment, which entrepreneurs often mentioned as a strong incentive for modernization.

Let us examine these points in some detail and describe how their interaction has resulted in changes in production processes and industrial organization. Before we proceed, however, it must be noted that firms do not supply precise information about strategic automation plans even to the Government. At the time of CEAM's study, assemblers refused to disclose their plans on the grounds that they were company secrets. Through our visits to the major assemblers, however, we have managed to get a general overview of what they are currently doing or planning to do in the near future to introduce new technologies, as will be discussed below.

The sharp decline in automobile sales in 1981 left much of the existing (rather inflexible) capacity underutilized. In 1981, about 110,000 workers were laid off by the industry as a whole and about 30,000 by the assemblers (Table 2). Since then competition has become fiercer, forcing the assemblers to reduce costs by means of more efficient organization and more flexible production techniques, and to enhance the appeal to consumers by releasing higher quality basic car models.

To a certain extent, the introduction of new technologies has been intended to increase production flexibility and reduce inventories. The latter goal also required more efficient handling of materials and organization of the production system. Virtually all assemblers now adopt some form of the 'just-in-time system' (calling it 'Kamban', 'minimum inventory system—SIM', etc.) in order to increase productivity, although it is still confined within individual companies and there is not a single case involving subcontractors. QC circles have also been widely implemented. The extent and forms of organizational change vary according to the degree of cooperation that the employer can secure from his employees and the latter's mentality and abilities and according to the technical standards adopted.

Substitution of new automation technologies for old equipment is still in its initial phase and has limits of its own. Although it tends directly or indirectly to increase productivity, it also implies heavy depreciation allowances and large capital investment which act as a deterrent. The cost of displacement of underdepreciated equipment is another problem. A plant manager in a large truck factory said, 'I wish I could substitute 20 NC machine tools for 100 general-purpose machine tools in my tool room, but what am I to do with the replaced equipment? No one wants to buy it, even if I offered it at bargain prices.'

The need to attract consumers in the domestic market has stimulated the release of new and more sophisticated cars. As indicated earlier, two of the four major car assemblers had been manufacturing a 'world car' by the time of
our visit, and the other two followed suit in 1984. One important consequence of this move is that it has created an ideal opportunity for heavy investment in production facilities and for the implementation of new managerial procedures. All the assemblers in our survey believed that application of advanced technology was required right away so that the workers could get used to it and receive adequate training, and that they would not lag far behind the international trend of production technology. The main objective is to pursue efficiency with flexibility and good quality control. As parts and components of the cars are exchanged among different plants in various parts of the world, one needs to be absolutely sure of their quality.

The engine of the first world car released in Brazil is manufactured by a flexible transfer line, which is controlled by approximately 130 programmable controllers (IPC-ISSC). The time required for reprogramming and setting up the system anew is thereby drastically cut. At the time of writing, this type of flexible transfer line produced six different engine models. The system’s capacity was about 2000 engines per day and 90 per cent of the output was exported. At the same plant site the firm has modernized the aluminium foundry by installing two casting robots.

The producer of the second world car uses eight welding robots, which are now common in Brazil, a robot painting chamber and two electronically controlled and flexible multispot welders which perform their functions extremely rapidly. Its welding robots and robot painting chamber were the first of their kind in the country. This company has also taken the opportunity to modernize its plant by massively introducing programmable controllers in lining up wheels, testing and selecting parts, allocating materials throughout the assembly line, etc.

In actual fact, these flexible multispot welders had been introduced by another assembler early in the decade, when the company released a new model (which was not called a ‘world car’ as yet). They are fed by electronically controlled magnetic trolleys. In 1984, the world car manufactured by this company was in the market and five welding robots were used initially for its production.

The fourth assembler has no plan for introducing microelectronic equipment, except the testing equipment which the firm has been using for the production of diesel engines for export.

We have noted that assemblers are increasingly seeking opportunities to use microelectronic devices—such as programmable controllers—to automate even their old production lines. This is the case, for instance, with the final testing of engines and assembled cars, or of the allocation systems which coordinate the supply of parts and components for the different models to the assembly line. However, old technologies are sometimes adequately used to meet the latest needs, as is the case with a firm which provides this coordination through the use of a conventional but very efficient telex network within the plant.

The pace of production technology innovation in the industry is dictated by
that of the introduction of new basic models. All the forthcoming models are associated with major automation plans. Only one firm had no such plan, but conceded that some automation equipment would be introduced such as air lift conveyors ('translift') and systems to hold the body of the car together during welding ('mascherom'), both controlled by microelectronic devices. At present this firm uses only two NC machine tools in car production (and two others in truck production), as low-volume production machines.

All four major car producers also assemble trucks. They seem to be following a general strategy similar to what we have already discussed with respect to car assembly, except that this is a far less dynamic market and production lines often employ more conventional methods.

Three subsidiaries of European corporations specialize in production of trucks and buses. The concept of a world vehicle seems to prevail at two of them. The third one has been established in Brazil for about 25 years and its basic models have changed little over the period. They all have a problem of underutilization of capacity but the extent of application of microelectronic equipment varies (Table 3). One firm has been using new technologies—

<table>
<thead>
<tr>
<th>Firm</th>
<th>Robots</th>
<th>NC machine tools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Kind</td>
</tr>
<tr>
<td></td>
<td>Use</td>
<td></td>
</tr>
<tr>
<td>Car assembler A</td>
<td>Spot welding</td>
<td>Lathes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measuring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
</tr>
<tr>
<td>Car assembler B</td>
<td>Casting</td>
<td>Milling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measuring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Machining centres</td>
</tr>
<tr>
<td>Car assembler C</td>
<td>Spot welding</td>
<td>Lathes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Painting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other (punching)</td>
</tr>
<tr>
<td>Car assembler D</td>
<td>—</td>
<td>Lathes</td>
</tr>
<tr>
<td>Truck producer E</td>
<td>—</td>
<td>Lathes</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>Machining centres</td>
</tr>
<tr>
<td>Truck producer F</td>
<td>—</td>
<td>Lathes</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>Machining centres</td>
</tr>
<tr>
<td>Truck producer G</td>
<td>—</td>
<td>Other (punching)</td>
</tr>
<tr>
<td>Jeep producer</td>
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<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>40</td>
</tr>
</tbody>
</table>

*Used in a truck plant.
mostly NC machine tools—since 1975, and another firm has just begun to use NC machine tools though not for the sake of flexibility but as low-volume machines. The third producer, recently established in a relatively modern plant, uses no microelectronic equipment. Among all three producers we found the same tendencies towards reducing inventories, adopting more efficient organization methods, producing a surplus in their trade balance, etc. Like the car assemblers, they introduce microelectronic equipment to replace conventional machines when their economic lives come to an end.

Surprising though it may seem, the only Japanese subsidiary in the Brazilian automobile industry is precisely the one that uses the most traditional production methods. It has a capacity to produce about 500 diesel jeeps per month, but the production level at the time of our visit was just over 50 per cent of the capacity. Not a single microelectronic device is used to automate the plant. However, there is a very efficient internal 'Kamban system'. They told us there was still much to be done in the way of improving production organization using the existing traditional equipment: each worker produced one vehicle per month as compared with five vehicles in Japan. There is no plan for plant modernization. As regards its integration into the world market, one of the company's staff members stated that 'in order to gain the necessary competitiveness, all efforts have been directed to increasing the productivity of our parent company factory in Japan'. The Brazilian plant therefore seems not to be intended for export.

Among microelectronic equipment, NC machine tools are the ones for which local production capacity has been most highly developed. This capacity has been developing since the mid-1970s. By 1980 six firms were producing the equipment regularly. Two of them were owned by Brazilian private capital and four by capital from the Federal Republic of Germany. At the Mechanics Fair held in São Paulo in 1982, sixteen firms displayed different types of NC equipment (again the majority of those companies were owned by firms in the Federal Republic of Germany). The skills for producing the electromechanical part of the equipment could be found locally, thanks to the existence of a traditional and well-developed machine tool industry in Brazil. Such skills have also been brought from the Federal Republic of Germany. The capacity for designing and producing NC units has been the object of specific technology transfer policy formulated by the Special Secretariat for Informatics (SEI). There are four companies owned by Brazilian private capital which are producing NC units. They have bought NC designs from foreign firms and have spent four years in absorbing their respective technologies. Since the volume of production is modest, however, the NC machine tools produced in Brazil cost two to three times the price of their counterparts in the world market. Consequently the number of NC machine tools installed in the industry is still limited. The car assemblers are using at least 21 NC machine tools (Table 3). They have been introduced where versatility and flexibility are required in the machining of small batches of complex-shaped parts (mostly in tool rooms) independently of the release of new models. The flexible manufacturing system (FMS) has not been introduced in Brazil yet.
None of the assemblers has introduced CAD yet but most of them intend to do so in the near future mainly for two purposes: (a) to increase the designing capability and thus independence from principal firms; (b) to become integrated into the latter firms' global system of production by increasing interchangeability of design and production plans.

The forms of new technologies with which we are now dealing—NC machine tools, robots and programmable controllers—may be used in different processes for different purposes. Table 4 shows the mode and purposes of the application of microelectronic equipment by four car manufacturers and one truck producer who are now using such equipment most intensively. The matrix suggests (where at least two assemblers score an average rate of four points or more) that the use of microelectronic equipment aims at:

(a) greater flexibility in production facilities;
(b) better quality and more strict quality control;
(c) better control of production flows;
(d) better working environment including safety; and
(e) speed-up of production (productivity).

Only in spot welding did skill saving appear to have motivated assemblers somewhat strongly to use the new technology. What is more, labour saving is not an important reason for the introduction of the microelectronic equipment. This seems to be verified in the light of the following exercise concerning the pay-off periods of painting and spot-welding robots in the Brazilian automobile industry.

We start with a basic formula developed by Caulliraux and Valle (1983):\

\[ P = \frac{I}{L - E} \]

where \( P \) = pay-off period, \( I \) = cost of buying and installing a robot, \( L \) = labour savings by the introduction of a robot, and \( E \) = maintenance costs.

As regards painting, a 'Nordson Robot System' has an estimated cost of US $110 000,\(^17\) which, multiplied by 1.5 to account for installation and working costs, gives us the value of \( I \). \( E \) is estimated at US $4500. As reported by user firms, one robot replaces two workers who earn two minimum wages per month per shift. Data on wages supplied by four assemblers are summarized in Table 5. On this basis the annual labour-cost saving is estimated at US $2430 per worker per shift. The pay-off period is then:

\[ P = \frac{110 000 \times 1.5}{(4 \times 2430) - 4500} = 32 \text{ years.} \]

As for spot welding, the robot is estimated to cost US $50 000 and double shift workers in welding earn 2.5 minimum wages/month. The pay-off period is then about ten years, i.e.:

\[ P = \frac{50 000 \times 1.5}{(4 \times 2040) - 4500} = 10 \text{ years.} \]
Table 4: Mode and purposes of microelectronic technology application at assembly plants

<table>
<thead>
<tr>
<th>Reason to automate using micro-electronic equipment</th>
<th>Reducing production of scrapped parts</th>
<th>Absorbing technology (learning)</th>
<th>Increasing the pace of production (productivity)</th>
<th>Reducing labour skills (skill saving)</th>
<th>Labour savings</th>
<th>Better working environment including safety</th>
<th>Increased control of production flows</th>
<th>Better and/or more regular quality</th>
<th>Greater flexibility in production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes and/or activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Machining</td>
<td>5</td>
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<td>4.3</td>
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<td>Machine feeding</td>
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<td>1</td>
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<td>4</td>
<td>1.5</td>
<td>1.2</td>
<td>2</td>
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<tr>
<td>Manipulation and transport of materials</td>
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<td>4.5</td>
<td>1</td>
<td>2.5</td>
<td>4.3</td>
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<td>2.2</td>
<td>4.5</td>
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<td>Foundry/forging</td>
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<td>3</td>
<td>2.5</td>
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<td>4.5</td>
<td>4.5</td>
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<td>Stamping</td>
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<td>3.7</td>
<td>3.5</td>
<td>3.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Controlling the flows of energy, parts, models etc.</td>
<td></td>
<td>5</td>
<td>4</td>
<td>3.3</td>
<td>2</td>
<td>2.7</td>
<td>3.3</td>
<td>4.7</td>
<td>3.7</td>
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<tr>
<td>Quality control</td>
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<td>3.5</td>
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<td>Arc welding</td>
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<td>4</td>
<td>2</td>
<td>5</td>
<td>4.5</td>
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<td>2.2</td>
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<td>4.3</td>
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<td>Painting</td>
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<td>1</td>
<td>5</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>Production management</td>
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<td>5</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Notes
1. The matrix indicates the order of importance (5 being the highest) of the reasons which led companies to introduce microelectronic equipment (robots, NC machine tools, programmable controllers, etc.).
2. On the upper left part of the square we have registered the simple average of the answers; on the lower right we have indicated the number of responses registered in each square.
3. The last two rows and the first two columns were originally headed 'Others—please specify' and were filled out by only one assembler.
Table 5: Wages in the assembly sector without fringe benefits (US$/hour)

<table>
<thead>
<tr>
<th>Job</th>
<th>Estimated average wage</th>
<th>Minimum average reported</th>
<th>Maximum average reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painting</td>
<td>0.98</td>
<td>0.69</td>
<td>1.23</td>
</tr>
<tr>
<td>Welding</td>
<td>1.08</td>
<td>0.90</td>
<td>1.23</td>
</tr>
<tr>
<td>Tooling</td>
<td>1.68</td>
<td>1.40</td>
<td>1.90</td>
</tr>
<tr>
<td>Mechanical maintenance</td>
<td>1.36</td>
<td>1.27</td>
<td>1.40</td>
</tr>
<tr>
<td>Electrical/electronic maintenance</td>
<td>1.75</td>
<td>1.26</td>
<td>2.69</td>
</tr>
</tbody>
</table>

*Calculated at the exchange rate of Cr$1.311/US$1.00 as of March 1984. The salaries indicated are those prevailing in March 1984, and not a yearly average. This is important in view of the distortions caused by the high rate of inflation in the country.

These results must be treated with caution, as the wage figures used might underestimate the actual labour cost by about 50 per cent because of the high rate of inflation in the country. It is clear, however, that in view of the wage figures above, the pay-off period of this equipment would be much longer in Brazil than in Europe, the United States or Japan, and it is unlikely to be used widely for the purpose of saving labour cost.

One might argue that, in the future, wages might rise substantially in Brazil and change the current conditions, but there is no such trend in sight for the time being. Many contradictory factors should be taken into consideration in making a more substantive analysis. For example, the savings in labour costs may accrue not only from the replacement of workers by the equipment but also from gains in the factory’s overall productivity. Moreover, in general terms, there are important social, political and cultural factors—and even some macro-economic implications—the evolution of which is difficult to predict.

3 AUTO-PARTS MANUFACTURERS AND MICROELECTRONICS

(i) The structure of the auto-parts manufacturing sector

There are over 1600 parts producers in Brazil, of whom over 600 are associated with SINDIPECAS. The latter are mostly large firms which supply parts directly to assemblers. A vast majority of them are concentrated in the Great São Paulo area, where most assemblers are also located.

These firms are certainly smaller than assemblers but as a whole they employ about twice as many workers as the assemblers do (Table 2). In terms of sales, their market consists of different segments as shown in Table 6. The intensity and form of competition vary considerably from one segment of the
Table 6: Auto-parts sales by type of market

<table>
<thead>
<tr>
<th>Type of market</th>
<th>Average: Dec. 81/Nov. 82 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturers of vehicles, tractors,</td>
<td></td>
</tr>
<tr>
<td>motors and components</td>
<td>60.0</td>
</tr>
<tr>
<td>Exports</td>
<td>4.0</td>
</tr>
<tr>
<td>Replacement market</td>
<td>28.0</td>
</tr>
<tr>
<td>Others</td>
<td>8.0</td>
</tr>
</tbody>
</table>

From SINDIPECAS em Noticias, February 1983.

market to another. Many firms produce not only auto-parts but also other products. Firms often supply to more than one assembler. To a certain extent this discourages assemblers from granting direct financial and technical support because they are afraid that their competitors might indirectly reap benefits from such assistance. This is also part of the explanation for the non-existence of the 'just-in-time system' involving subcontractors. Recently, auto-parts manufacturers have been concerned about an increasing degree of vertical integration by the assemblers as a result of the 'world car' programmes. The assemblers' share in the total shipments by the local auto-parts manufacturers declined from 70.7 per cent in 1978 to 59.9 per cent in 1982. In the meantime, the decline in automobile production in 1981 caused dismissal of about 81,000 workers in the auto-parts sector against 29,000 at the assemblers' plants.

The crisis has affected different segments of the sector in different and often contradictory ways. It sometimes acts as a deterrent, but at times it provides—directly or indirectly—the stimulus to investment in new technologies. To begin with, the reduction in orders from the assemblers has caused a considerable underutilization of existing production facilities, some of which still need to be paid off. This is detrimental to new investments. Credit has been restricted and interest rates raised. Larger firms are more likely to overcome financial constraints than smaller ones, and foreign subsidiaries are more likely to obtain financial support either from their principal firms or from the international banking system. The smaller local firms are severely affected by the shortage of working capital and high interest rates. We have detected a serious concern that the sector may thus become more denationalized through the acquisition of local firms by foreign subsidiaries.

Another factor which handicaps smaller local firms is one of the basic BEFIEX requirements for export incentives. Because of their weak international links, these companies (in contrast with foreign subsidiaries) cannot guarantee a minimum level of exports for long periods of time: 'In the first place, the auto-parts exports strategy has been characterized by the exploitation of niches in the Latin American market. The commitment concerning pre-established export levels for long periods, as required by BEFIEX, was
Table 7: Auto-parts sales and exports
(in US$ million)

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales$</th>
<th>Exports$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>2504</td>
<td>40.4</td>
</tr>
<tr>
<td>1975</td>
<td>2707</td>
<td>43.2</td>
</tr>
<tr>
<td>1976</td>
<td>3186</td>
<td>55.9</td>
</tr>
<tr>
<td>1977</td>
<td>3379</td>
<td>82.5</td>
</tr>
<tr>
<td>1978</td>
<td>4447</td>
<td>127.7</td>
</tr>
<tr>
<td>1979</td>
<td>4967</td>
<td>166.6</td>
</tr>
<tr>
<td>1980</td>
<td>5464</td>
<td>211.1</td>
</tr>
<tr>
<td>1981</td>
<td>5116</td>
<td>271.2</td>
</tr>
</tbody>
</table>

$^a$From SINDIPECAS.

$^b$From CACEX.

inappropriate for firms which utilized the external market as an alternative, given the high instability of that market. Engagement in these programmes seemed restricted to foreign firms, who could ensure quotas in their countries of origin, depending on the strategies of expansion of those firms at the world level, or confined itself to large national companies already linked with the external market. Second, participation in BEFIEX's programmes was discouraged by the high level of investment previously made in the sector in the early seventies. The BEFIEX programmes reduce the cost of imported modern equipment and thus accelerate the diffusion of microelectronic equipment. This also tends to increase imbalances within the sector. Some local firms have been trying to overcome their handicap through the establishment of joint ventures.

Exports of auto-parts increased from US $40.4 million in 1974 to US $271.2 million in 1981 (Table 7). Although they represented only 4 per cent of the sector's sales in 1982 (Table 6), they are certainly a promising option for enabling larger firms and foreign subsidiaries to maintain higher rates of capacity utilization.

(ii) Diffusion of microelectronic equipment

The drive towards exports as a way out of the crisis is surely a factor that accelerates the introduction of microelectronic equipment, since high-quality standards, flexible production and efficient organization are decisive requirements to enable firms to face international competition. In 1971, auto-parts producers in Brazil exported to 33 countries (82 per cent of the total amount to four countries). As of 1980, auto-parts were exported to 114 countries (and only two producers accounted for more than 10 per cent of the total exports).19

The growing importance of export markets and the release of 'world cars' have stimulated the modernization of the sector not only in production but
also in design capacity. CAD has already been introduced by a few firms and others are seriously considering its introduction in the near future, although the engineering designs of ‘world car’ parts are not prepared by local parts producers but are received from the assemblers.

The assembler’s policy of reducing inventories has also been encouraging the introduction of new technologies into the auto-parts sector. While the market for automobiles continued growing, orders were given to parts manufacturers six months in advance and confirmed one month prior to delivery. Nowadays, however, orders are very erratic. They are generally confirmed with a week’s notice but one-day notices are not altogether uncommon. Suppliers complained bitterly about this. A few of the larger firms and foreign subsidiaries, along with some of the assemblers, have been studying the possibility of establishing direct intercomputer placement of orders so as to increase the efficiency of production integration, although no actual move in this direction has been made as yet.

The need to assure uniformity of quality and respond quickly to order changes (both regarding quantity and specifications) is definitely a powerful factor inducing auto-parts makers to adopt more flexible and efficient production methods, i.e. microelectronic equipment. A member of the Board of Directors of ABIMAQ (the Brazilian Association of Machine Industries) mentioned that most inquiries about this type of equipment received by ABIMAQ members come from the auto-parts sector.

Parts makers almost exclusively working for truck assemblers have an additional reason for using NC machine tools, viz. the low volume of production. Moreover, their products are often subject to modular variations in the same basic truck models, thus facilitating automation. Two axle producers who use large numbers of NC machine tools do not employ them in tooling but rather use them as production machines in ingeniously integrated flexible systems.

According to information from various sources, at least 50 parts makers were using over 150 NC machine tools, which if added to NC machine tools used by car and truck assemblers accounted for about 20 per cent of the total stock of NC machine tools in Brazil (some 900) at the time of our survey. They are used mostly in tool rooms, but a larger number of such machines are used for low-volume production of parts and components rather than by the assembly sector. Two-thirds of the user firms had some foreign capital participation and about 50 per cent could be considered foreign-owned (i.e. a participation of over 50 per cent by foreign capital). The fourteen respondents to our questionnaire reported 71 NC machine tools, out of which 62 per cent were lathes and 17 per cent were machining centres (Table 8).

Our findings summarized in Table 8 are consistent with the general pattern of diffusion of NC machine tools in Brazil. In a questionnaire survey in 1983, 73 per cent of the NC machine tools were used by firms with 500 or more workers and 69 per cent of the sample firms in this size group used NC machine tools. Eight out of the ten largest firms (in terms of gross operational
Table 8: NC machine tool utilization by firm size and by type of equipment
(number of units of machines)

<table>
<thead>
<tr>
<th>Size of firms (No. of workers)</th>
<th>Lathes</th>
<th>Machining centres</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 100 (1)</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>100–499 (4)</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>500 or more (9)</td>
<td>33</td>
<td>9</td>
<td>10</td>
<td>52</td>
</tr>
<tr>
<td>Total (14)</td>
<td>44</td>
<td>12</td>
<td>15</td>
<td>71</td>
</tr>
</tbody>
</table>

Note
Figures in parentheses indicate the numbers of sample firms in the different size groups.

revenues) were NC machine tool users. Similarly, in the author's previous study, 66 per cent of all users (76 firms) employed over 500 workers and 62 per cent were foreign-owned. Not only can they better afford to purchase such equipment than smaller firms, but they are also better informed about technological developments elsewhere. It is also true that export-oriented firms appear to be more enthusiastic about introducing new technologies: the firms using NC machine tools exported 25 per cent of their output as compared with about 4 per cent in the sector as a whole.

Motivation for introducing NC machine tools is in line with all that has been stated so far: quality control, flexibility in production and the characteristics of certain products (Table 9). The assemblers had not played any direct part

Table 9: Motivation for microelectronic equipment application

<table>
<thead>
<tr>
<th>Criterion</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality improvement</td>
<td>34.4</td>
</tr>
<tr>
<td>Production flexibility</td>
<td>33.0</td>
</tr>
<tr>
<td>Competitiveness</td>
<td>32.7</td>
</tr>
<tr>
<td>Work which is difficult or impossible with conventional machines</td>
<td>27.5</td>
</tr>
<tr>
<td>Unit cost reduction</td>
<td>25.6</td>
</tr>
<tr>
<td>Control over production process</td>
<td>25.0</td>
</tr>
<tr>
<td>Scarcity of skilled labour</td>
<td>9.0</td>
</tr>
<tr>
<td>Foreign market requirements</td>
<td>3.0</td>
</tr>
<tr>
<td>Assemblers' requests</td>
<td>1.0</td>
</tr>
<tr>
<td>Other</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Notes
1. The number of sample firms was 14.
2. Each firm gave more than one answer.
in the decision-making by the parts makers. The need to increase competitiveness, the need to reduce unit costs and the need to control the production process were also among the most frequent consideration, although they obviously overlap (Table 8). Contrary to the reasonably well established view, the scarcity of skilled labour was rather played down.

Although the initial investment required for the introduction of NC machine tools is large, unit costs decrease because better planning and control of the production processes reduce idle labour and the downtime of equipment. Moreover, a wider range of products can be produced, their quality is improved, a greater production flexibility is achieved and delivery time is shortened, thus rendering the investment in NC machine tools very efficient and increasing the competitiveness of the firms. All our respondents intended to buy additional NC machine tools (50 per cent planned to do so next year), proof of how satisfied they are. However, half of them had not made any *a posteriori* economic study to confirm the advantages of the new equipment.

As pointed out earlier, the assemblers have not interfered in the auto-parts producers' decision to automate their plants. In reply to a specific question whether they had received any financial or technical support from assemblers regarding NC machine tools, all the firms gave a negative answer. The only exception was a company which acknowledged some aid received in the form of courses and technical information.

Main obstacles to the diffusion of NC machine tools seem to be the high cost of such equipment, the country's economic crisis and low labour costs (Table 10).

None of the parts makers in our survey intended to use robots in the near future. According to them, labour costs were too small a proportion of total production costs to justify labour substitution by robots where they might be technically suitable, as is clearly the case, for instance, in loading and unloading, tool changing, etc.\(^{22}\)

<table>
<thead>
<tr>
<th>Table 10: Major obstacles to the diffusion of NC machine tools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Obstacles</strong></td>
</tr>
<tr>
<td>High price of the equipment</td>
</tr>
<tr>
<td>Brazilian economic crisis</td>
</tr>
<tr>
<td>Low labour costs</td>
</tr>
<tr>
<td>High social costs of automation</td>
</tr>
<tr>
<td>Poor technical assistance</td>
</tr>
<tr>
<td>Low quality of locally produced automated equipment</td>
</tr>
</tbody>
</table>

*Note*

The number of sample firms was 14.
4 IMPACT ON EMPLOYMENT AND LABOUR

(i) Employment impact and workers’ attitude

No solid data base exists to permit a systematic evaluation of the impact of the diffusion of microelectronic technologies upon employment in Brazil. However, the creation of the Special Commission for Manufacturing Automation (CEAM) by the Special Secretariat for Informatics (SEI) at least shows the Government’s concern about the matter. The reports prepared by its subcommittees contain two tentative estimates of the employment impact of new technologies up to 1990. One of them, prepared by J. C. Peliano (1983), suggests that 800,000–2,400,000 jobs may be lost in Brazilian manufacturing industries during the forthcoming period. This estimate is based on the highly questionable assumption that the microelectronic automation process in this country will follow the same pattern and pace as the recent forecasts by the Carnegie Mellon Institute for United States industry during the same period. More realistic is the study by S. Rocha (1982), which considers three different scenarios regarding the rate of diffusion of microelectronics. Assuming a total stock of equipment (NC machine tools, robots and CAD systems) at 2000, 10,000 or 40,000 units in 1990, Rocha estimates that the corresponding range of labour replacement would be in the order of 4000–16,000, 20,000–80,000 and 88,000–352,000 jobs, respectively.

The only empirical data on labour displacement by microelectronic equipment in Brazil that are quoted in the CEAM/SEI report were drawn from a study conducted by the present author. In that study, a large majority of users indicated that NC machine tools replaced between three and five conventional general-purpose machines. This means that between 4200 and 7000 jobs of general-purpose machine tool operators had been displaced by the 700 NC machine tools installed in Brazil by 1980. On the other hand, 2200 workers were reported to be working with NC machine tools, including operators, programmers, etc., and excluding mechanical maintenance, which probably would exist in any case. It follows that there was a net direct loss of 2000–4800 jobs out of a total of 4200–7000 positions affected (between 48 per cent and 69 per cent).

Findings of that study by the author also appear to be relevant to the automobile industry. For example, our questionnaire and visits in this industry have confirmed that each NC machine tool replaced, on an average, three to five general-purpose non-automatic machine tools. The majority of NC machine tools in Brazil are attended individually by a worker. Thus, the use of about 190 NC machine tools (150 in the parts manufacturing sector and 40 in the assembly sector) must have replaced between 570 and 950 conventional machine tools and caused a loss of approximately 1140–1900 conventional machine operators’ jobs in two shifts. If the ratio of new jobs directly related to the NC machine tools to the conventional jobs lost is assumed to be the same as in the earlier study, only about 600 new job positions will have been
directly recovered within the industry, including about 380 NC machine tool operators and about 220 programmers and other microelectronic staff. Of course, there are some counterbalancing factors which are very difficult to measure (such as the increase in the competitiveness of user firms and the creation of job positions by the local producers of the equipment) and which should be taken into account in a more precise assessment of the overall net effects on employment.

In so far as one can tell from Table 1, the productivity of labour in the assembly sector measured in terms of the number of vehicles produced per worker in 1984 was below the level achieved in 1975, although it was higher than in 1981 and 1982. The volume of employment in the industry including the parts manufacturing sector fluctuates with the level of vehicle production. In the parts manufacturing sector, it must have been affected also by the declining local content ratio of the Brazilian automobiles, although no quantitative assessment has been attempted yet.

Clearly, the current amount of technological unemployment in Brazil is, if it exists at all, marginal as compared with that of conjunctural and structural unemployment. Under the circumstances, it is understandable that Brazilian workers give a low priority to technological issues as discovered by a study conducted in early 1983. For this study, DIEESE distributed 19 500 questionnaires among metalworkers at 21 firms in Santo André (part of the Great São Paulo area). They received replies from 12 per cent of the workers. We had access to the raw data relating to workers of five auto-parts firms. Control over mechanization and robotization ranked lowest among six alternatives presented to workers as the slogan for the 1983 wage campaign, attracting only 3.8 per cent of the replies. Their main concerns were: job stability (31.8 per cent), union representation within plants (26.2 per cent) and workers’ commissions, which are intended among other things, to improve working conditions at the workshop level (19.3 per cent).

The fact is that the Brazilian working class now faces a new technological situation, brought about by the diffusion of microelectronics, before it has become thoroughly familiar with the conventional electromechanical equipment. The local working class appears to be shocked by the new horizon opened up by the new technologies, and in early 1982, for the first time in their history, Brazilian unions did include technological issues—workers’ protection from undesirable effects of technological progress, job stability, guarantee of retraining, etc.—in their agenda of negotiations with employers, who immediately dismissed the subject without offering any alternative proposals.

We had several contacts with unions and representatives of factory commissions. Virtually all of them were very concerned about the consequences of the introduction of microelectronic equipment, but did not understand its rationale and had done nothing to monitor its consequences. The only exception was a factory commission which was planning to analyse the labour content of the production line related to a vehicle model which had gone out
of production two years earlier and compare it with the one related to a new model released at about the same time. The assembler had not only refused to cooperate with the commission but regarded the study as a sign of antagonism on the part of the workers. Nonetheless, other factory commissions and unions intended to make similar attempts shortly.

It is our understanding that the creation of CEAM was aimed at promoting harmony in industrial relations, as stated in the following recommendation included in its report:

The intensity and rhythm of NT (new technology) adoption should be adequate to preserve mastery over the production processes that are altered and over technological memory, to minimize the foreseeable negative effects on labour, and to reduce the impact arising from the increase in technical efficiency upon inter-industrial relations.25

The report's major suggestions concerning employment are: (a) strengthening the programme of retraining, vocational training and education in general; (b) raising of the minimum age limit for entry into the labour market; (c) guaranteeing that labour will not be displaced for at least a certain period after the introduction of new technologies; (d) improving the Government's commitment to the social security policy related to unemployment and other negative effects that may arise from the adoption of microelectronic equipment including creation of an unemployment insurance scheme; (e) strict control over extra working hours; (f) reduction of the working day; and (g) sharing of productivity gains with workers.

The report further suggests that labour legislation be modernized to satisfy all parties involved and that, at the company level, some form of workers' participation be created to work out the inevitable problems caused by new technologies. Specifically, workers' participation should cover (a) control over the rhythm and intensity of the work pace; (b) the work environment; (c) occupational classification; (d) access to information about equipment, processes and data that interfere in workers' activities.

CEAM's report is a sort of declaration of intent which may or may not be realized, but it reveals the serious lack of a social infrastructure capable of avoiding possible harmful consequences of the diffusion of microelectronic technologies.

(ii) Effects on work organization

New technologies are likely to produce organizational changes. Eight out of fourteen auto-parts producers who responded to our questionnaire had expanded or created new departments (e.g. programming, maintenance of electronic components of their equipment, NC tooling, etc.) in their plants and most firms were equipped for their own programming and maintenance.

All the firms visited, as well as those which replied to our questionnaire, stated that NC machine tool operators and programmers were selected from among their own personnel. Over half of these firms paid higher wages to NC
machine tool operators than to operators of conventional equipment. At the same time, workers became more formally trained, thus paving the way for a career from the shopfloor into the office. On the other hand, microelectronic-based automation increases the possibilities of moving planning and control away from the shop, perhaps eventually moving control to offices located at very great distances such as a different state or even a different country, which could have profound implications for the international division of labour.

Thanks to the systemic nature of their technical knowledge, new production workers have been able to use it as a skill for planning the process formally. In Brazil, it is not uncommon to find programmers who were formerly NC machine tool operators and a considerable number of programmers we met were studying engineering (or were already engineers). In the meantime, computer programming is becoming a part of routine work although only about 20 per cent of our respondents indicated they were doing it.

In terms of qualification as NC machine tool operators, the employers' views were divided between two extremes: some firms preferred newly trained young workers who might quickly get used to the new technical culture, while others would rather choose workers who had considerable experience with conventional machines to entrust with expensive and strategic equipment. There seems to be some sort of barrier to retraining older workers to operate microelectronic equipment. In many cases, however, these workers' practical experience remains a valuable asset to the firms.

5 SUMMARY AND CONCLUSIONS

The Brazilian industrialization in the last 30 years or so has been largely stimulated by the establishment of a local automobile industry, which induced development of other industries through linkage effects. The Government decisively supported it by creating the basic material infrastructure necessary for its development.

The central argument of our study is that the Brazilian automobile industry seems to be on the verge of new and major restructuring in which internationalization of its market and supply base will proceed hand in hand with the transformation of its technical base. The dynamics of the world's automobile industry, together with the current conditions of the Brazilian economy, are the main driving force for such changes.

The leaders of the world's automobile industry are currently engaged in a process of intensified competition where microelectronic technologies are becoming a crucial factor, eroding and 'transforming the basis of the international division of labour in ways which have the most serious consequences for the periphery'.

The current economic crisis has caused a slump in car sales in Brazil and a consequent increase in underutilization of capacity. Competition has therefore increased and the automobile industry has been forced to reorganize and
modernize itself, entering a new phase of its development. Exports have received greater emphasis both as a way to decrease the underutilized capacity of firms and as a means of helping to overcome the country's deficit in the balance of payments.

Gone is the time when concerns with costs and overall economic efficiency were played down. In those days, the important thing was to be able to produce. Costs were calculated afterwards. Today, the parameters are the prevailing international costs, quality standards, versatility and speed of delivery. In order to compete successfully, these requirements must be met. Microelectronic equipment has provided Brazilian firms with a convenient means to this end. The assemblers have introduced welding, painting and other robots as well as NC machine tools in their tool rooms. Release of 'world cars' has provided, in most cases, an adequate opportunity for introduction of microelectronic equipment. In the auto-parts manufacturing sector, the most commonly used microelectronic equipment is NC machine tools. Programmable controllers and CAD systems are also beginning to be introduced. However, we discovered no plan to introduce robots in the auto-parts sector in the near future.

Partly because of the still very modest extent of application of microelectronic equipment—fewer than 20 robots and about 190 NC machine tools—in this industry, the amount of labour displacement caused by the new technology appears, if it exists at all, marginal compared with the enormous amount of structural and cyclical unemployment caused by the general depression of the economy. To illustrate this, it may be pointed out that the annual number of vehicles produced per worker in 1980–83 was below the 1975 level and in 1984 approximately equal to the level of 1973.

Workers' unions have just begun to voice their concern about the (potential) employment effect of microelectronic technologies. The issue, however, still receives a very low priority in their agenda of negotiations with employers in the face of the overwhelming impact of the current economic crisis.

The Government is concerned with the socioeconomic implications of the diffusion of microelectronic technologies in two ways. On the one hand, it is worried about the possible negative employment and other effects and exploring means to overcome them. On the other, it is trying to promote local—and indigenous—capacity to design and produce microelectronic equipment.

In this effort, Brazil is in a serious dilemma. The drive towards automation and the utilization of microelectronic technologies has been hampered by the government policy of protecting the national capital goods industry and by red tape. There have been general complaints about that. The complaints often seemed valid as regards, for example, the inability of the Government to distinguish what is important to protect (or forbid the import of) from what is not. Production facilities sometimes remain idle for long periods because of the difficulties in replacing a one-dollar microelectronic component. On the other hand, if no protection existed at all, the whole long-term strategy of
building local capacity to design and produce microelectronic equipment might come apart once and for all. Apart from such long-term macro-economic argument, there is a more immediate micro-economic dilemma: if there is a danger that excessive protection may hinder the adoption of the latest technologies, thereby reducing the competitiveness of local firms, there also is the fact that, without protection, some of the national firms are sure to be killed by international competition even before birth.

ACKNOWLEDGEMENTS

I am indebted to many entrepreneurs, managers, technicians, workers and colleagues for their patience and willingness in helping me in this research project. My special thanks are due to Renato T. Izar, who helped me in reviewing historical material, making contacts for visits and interviews and collecting and organizing statistical information, and to Fabio Erber and Susumu Watanabe, who carefully read and commented on the earlier drafts. Of course, the responsibility for the content of the text is entirely my own.

NOTES

1 Our analysis in Sections 2, 3 and 4 is based on (a) information obtained from official institutions; (b) visits to four major car assemblers (General Motors, Ford, Volkswagen and FIAT), three truck producers (Mercedes Benz, Saab Scania and Volvo) and one jeep producer, who account for over 98 per cent of total automobile production in Brazil in 1984; (c) visits to thirteen auto-parts producers including eight users of NC machine tools; and (d) replies to questionnaires sent to all the auto-parts producers whom we had identified as NC machine tool users. Fifty questionnaire forms were sent out but only fourteen were returned including seven of the thirteen auto-parts producers mentioned in (c) above. We also interviewed members of the boards of directors of manufacturers' associations like ANFAVEA (National Association of Motor Vehicles Manufacturers), SINDIPECAS (National Association of Auto-parts Manufacturers) and ABIMAQ (Brazilian Association of Machine Industries), as well as representatives of related government agencies like SEI (Special Secretariat of Informatics) and MIC (Ministry of Industry and Trade). Contacts were also made with trade unions through DIEESE (Inter-Union Bureau of Statistic and Socio-Economic Studies).

2 Aviso de CEXIM No. 288 of August 1952.


6 As note 5, pp. 158–9. 'Model' here refers to the whole array of list options for a smaller number of basic models.

7 Humphrey (1982), p. 89.


9 Sister (1983).

10 Gadelha and Lobão (1982).

11 APEC (1982).

12 Araujo (1982).

13 EXAME (1982).
15 On the concepts of the just-in-time system and QC circle, see Chapter I in this volume.
17 This value is given as a ‘typical’ configuration in the 1982 Robotics Industry Directory. It certainly includes the cost of motors but probably not tools. In Industrial Robots: Summary and Forecast for Manufacturing Engineers (Tektran Corp., Ill., USA, 1982, p. 96), accessories represent 24 per cent of the total cost of a painting robot amounting to US $110 000, and 30 per cent of that of a welding robot amounting to US $160 000.
18 Gadelha and Lobão (1982).
20 EXAmicroelectronic (1983).
22 Direct labour costs accounted for 4–25 per cent of total costs in the firms visited in this sector.

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CHAPTER VIII

A Synthesis of Findings

Susumu Watanabe

1 GENERAL CONCLUSIONS

Microelectronic machinery is usually introduced simultaneously with changes in work organization, product design, material and other production technology. The output level fluctuates and the product mix alters. Due to differences in the initial conditions, moreover, the impact of the new technology varies not only from country to country but even within a country, firm or plant. It is therefore extremely difficult to quantify its employment effect precisely. Nevertheless, the country case studies in this volume, together with supporting evidence published elsewhere, permit us to draw a number of conclusions. Our general conclusion is that microelectronic machinery can hardly be considered a major cause of the job losses that took place in North American and West European automobile industries after the late 1970s. More fundamental causes are reduced automobile production and rationalization programmes which sometimes involve a drastic change in the personnel policy or industrial relations. The rate of diffusion of microelectronic machinery has been much slower than anticipated and its systematic application, for example in the form of the flexible manufacturing system (FMS), is rare, apart from the body-welding robots.

The impact of microelectronic technology on employment at the industrial or enterprise level tends to be overestimated in two ways. On the one hand, its labour-saving effect is exaggerated, largely because assessments of it are usually based on observations at major plants: possibilities of different modes of application by smaller firms and underutilization of the new machinery installed are ignored. On the other, the existing literature neglects one important element of the compensating effect at the enterprise level, namely the fact that the very flexibility of microelectronic machinery tends to augment the average amount of work per unit of final output (vehicle) by encouraging product differentiation and shortening of the product cycle.

Even where the employment level in an industry or an enterprise remains unaffected by the new technology, however, individual workers’ jobs can be threatened by new recruits if they fail to adapt themselves to the technological progress and related organizational changes. Training and workers’ occupational and geographical mobility are therefore crucial to their job security.
The rest of the present chapter will elaborate upon these points and consider the prospect of diffusion of the new technology and its impact in the near future. Finally, a number of promising areas of further research will be identified on the basis of our studies.

2 THE EXTENT AND PATTERN OF MICROELECTRONICS
APPLICATION

The diffusion of microelectronic machines is still modest, although the pace of their diffusion accelerated towards the end of the 1970s in all the industrialized countries studied in this volume. They are usually introduced when a new vehicle model is launched. For this reason and also because of technical and economic constraints to be discussed below, the rate of diffusion of the new technology has been much slower than previously anticipated. Among the car makers in Western Europe only Volkswagen used more than 1000 robots in the mid-1985.

In the Brazilian automobile industry the use of robots is still rare, largely because of the low wage rates. The internationalization of multinational automobile manufacturers' operation, however, has been encouraging the application of NC machine tools for the purpose of manufacturing internationally exchangeable parts and components.

Most NC machines are used in tool rooms, for die-making, or as stand-alone machines in workshops. Although their labour-saving effect is maximized when they are used in a system (cf p. 61), their systematic use, for example in a flexible manufacturing system (FMS), is rare, and the existing FMSs are often still in the experimental stage. Apart from scattered cases of NC wire-cutting machines and EDMs, unmanned night shifts of stand-alone NC machines also remain exceptions. The same is the case with robots. Except for body welding, and to a lesser extent painting, their systematic use is limited.

There is a remarkable difference between Japan and other countries regarding the area of robotization. While in Japan the robots are employed mostly for welding and painting, their use is spread more widely in North America and Western Europe. The firms in these regions use substantial proportions of robots for material handling. As Seering points out in Chapter II, the Japanese try to organize work in such a way as to permit application of as simple and therefore as low-cost machines as possible. Preferring manipulators or other simple devices which are often developed and built by workers in the QC circle activity, they seldom use a robot for material handling. This is quite significant because, as Hunt and Hunt (1983) anticipate, in the United States 'the greatest number of jobs will be eliminated by pick-and-place robots performing machine loading and unloading functions'. It follows that the area of robotization which is currently most labour-saving in other countries is almost non-existent in Japan. One should thus expect a much smaller employment impact in this country. And this is what we found, as will be mentioned shortly.
Firms introduce NC machine tools and robots for flexibility (versatility and short lead time), which helps raise the rate of capital utilization by reducing downtime, for better or more regular quality of work, for saving labour, for overcoming shortages of skilled workers, for circumventing the problem of safety and health or for doing certain types of work that are simply impossible with conventional machines. Often more than one consideration influences the firm's investment decision. Depending on the initial conditions, the relative importance of various objectives differs from case to case even within the same firm or plant. It also varies over time as a result of changes in the input (e.g. labour and energy) market and product market. Sociopolitical climate also has significant influence, such as an increase in environmental concern.

Our findings in Chapters III–VI suggest, generally speaking, that the flexibility of microelectronic equipment is appreciated more in Japan than in Western Europe and North America, where the automobile producers use them more for saving labour in production work. In the United States Allen reports that 'greater flexibility was seldom mentioned' (p. 87, Chapter IV). Replacement of or substitution for automatic machines appears to remain a possibility in the future: '... as robots become more common in manufacturing processes, they will replace hard (= fixed) automation such as mechanical transfer devices, as well as human workers. This kind of substitution follows from the fact that industrial robots represent an intermediate technology between dedicated or hard automation and manual or human labour.'

This may be even more true in smaller countries where microelectronic machines provide opportunities for automation of such small and medium-sized batch production as is uneconomical with fixed automation equipment, as our reference to Sweden in Chapter I suggests. In contrast, the Japanese more usually use microelectronic equipment for the purpose of increasing flexibility. To save labour, they look to special-purpose machines and transfer machines and to simple devices such as chutes and stoppers: 'microelectronic machines are too slow'.

3 THE EMPLOYMENT IMPACT

The numbers of NC machine tools in major companies are marginal compared with the total machine populations in these firms. The areas of application are numerous, and frequently lie off the production line for occasional use in die-making, prototype production and trial production. Consequently these users do not usually come up with any definite assessment of labour displacement. The mode of application by small firms varies from case to case. So does the labour-saving effect as illustrated in Table 8, Chapter III. However, our case studies were not extensive enough to establish any definite ratios. An impression gained in Japan was that, by and large, a higher efficiency in capital utilization, quality of work (better or more regular quality of product, and complex work) and higher product values were more important considerations in applying NC machines than labour saving. In Brazil,
our country case studies estimate the maximum amount of labour savings possibly realized through robotization, as in Table 1. If the effects of micro-electronic equipment other than the robot are taken into account, labour savings become larger. Of course efforts at productivity improvements also took place in other domains: for example rationalization of work organization and product design. Even so, only in Japan and France was output per worker in 1983–84 substantially higher than the level attained in 1972–73 (Figure 1, Chapter I). In the former country, output per worker stopped rising and hours worked per vehicle somewhat increased after 1980, i.e. the very period when the diffusion of the new technology accelerated. Obviously the labour savings gained through microelectronic innovation and other improvements were more than offset by increased work per vehicle.

The analysis in Chapters V and VI shows that the productivity increase has been relatively large at the plants of dominant robot users such as Renault in France and FIAT in Italy. However, the increase in productivity at Renault was attributed more or less equally to three factors: rationalization of work organization, improvements in the product design and modernization of production technology (of which microelectronic machinery is only a part). In Italy, Silva, Ferri and Enrietti conclude that the state-supported rationalization programme aimed at trimming surplus labour has been the main contributor to the remarkable recovery of FIAT's efficiency. In the light of the rapid fall in production and delayed adjustment in the size of the workforce during 1978–82 (Figure 1, Chapter I), it seems safe to argue similarly with

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**Table 1: Estimates of maximum possible labour savings by robotization up to the end of 1984 or mid-1985 (in two shifts)**

| Country        | No. of robots | No. of workers replaced | Change in employment in the industry 1979–84 | (2)/(3) (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>10 000</td>
<td>7 000</td>
<td>+60 000</td>
<td>—</td>
</tr>
<tr>
<td>United States*</td>
<td>5 000–7 000</td>
<td>10 000–15 000</td>
<td>−300 000</td>
<td>3.3–5.0</td>
</tr>
<tr>
<td>France</td>
<td>800</td>
<td>1 000</td>
<td>−50 000</td>
<td>2.0</td>
</tr>
<tr>
<td>Italy (FIAT)</td>
<td>800</td>
<td>2 400</td>
<td>−68 432</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*Includes the robots installed in Canada.

Based on data in Chapters III–VI.
respect to the United States: that the recovery of output per worker after 1982 is a reflection of gradual elimination of overmanning rather than a result of microelectronic innovation. The rapid increase in the value added per work hour after 1981 (Table 1, Chapter IV) seems to be related to the 'voluntary export restriction' by the Japanese firms rather than to real increase in labour productivity. Output per worker in 1983-84 was lower than in 1972-73, despite the substantially reduced average vehicle size and greater dependence on imported parts and components.

Finally, in Brazil, employment changed more or less in parallel with automobile production, but the 1974 level of output per worker has never been surpassed.

From the above, we are inclined to conclude that the decreased employment in the automobile industry in most countries has been essentially a consequence of reduced automobile production as well as of general rationalization programmes. From Table 1, it is clear that the maximum job losses possibly attributable to the new technology are marginal compared with the total numbers of jobs lost.

Having said this, one cannot help asking two extremely interesting questions. One concerns the cause of the significant inter-country differences in the labour-saving effect of the new technology which emerge clearly in Table 1. Even more intriguing is the other question: how do the declines in output per worker go with microelectronic innovation and other efforts at productivity improvement? Where the overall production level declined, one important explanation could be found in institutional constraints which impede a thorough adjustment of the size of the workforce to the falling production, such as sociopolitical pressure against dismissal of workers. It is also possible that while the new machinery helps to save labour on certain production lines and workshops, it can increase labour requirements in some other cases (Table 8, Chapter III). To some extent, labour saving in a production process is offset by increased programming and maintenance work. All these explanations may be applicable, more or less, to different countries, but they are not quite enough to explain the situation in Japan. Our findings in that country and also at Peugeot in France suggest that there is one important element of 'compensating effect' at the enterprise level which has been neglected so far. We may call it 'work-amplifying effect'.

The next two subsections deal with these two questions in turn.

(i) The labour-saving effect

Two aspects of the labour-saving effect need to be distinguished: labour savings in actual production work such as machining, welding, painting and material handling, and labour savings in preproduction work. There is a general consensus of opinion that NC machine tools and robots are dramatically more efficient in the second area compared with conventional automation machinery because of their flexibility. Their efficiency in actual produc-
tion work varies, depending on the type of the machine and the degree of precision and difficulty of the work assigned to it. The programmer's quality will also count. However, the most important influencing factors are the degree of automation, the level of efficiency of work organization and the quality of workers that existed before the introduction of such machines. The last two factors are important, partly because they determine the number of conventional machines tended by a worker. (This may also be influenced by industrial relations.)

As noted in Chapter I, where the scale of production is very large, 'fixed automation' based on special-purpose machines and transfer machines is much more labour-saving than microelectronic 'flexible automation'. Major automobile and component producers try therefore to maximize opportunities for fixed automation, for example by using common parts and components on different models. An extreme case is SKF, the world-famous Swedish manufacturer of ball-bearings, which pursues economies of fixed automation through division of labour among sister factories located in different parts of the world that are each specialized in different sizes or types of ball-bearings. In certain areas (e.g. body welding), however, firms are obliged to replace fixed automation lines with flexible ones for the purpose of differentiating their products and shortening the product cycle. In doing so, they sacrifice productivity of labour in production work. On the other hand, there are countries and firms where fixed automation had not advanced much prior to the advent of microelectronics machinery. Here, flexible automation replaces manual work and creates significant labour-saving effects.

In Chapter III, it was shown that the Japanese automobile industry had been highly automated by the early 1970s through enormous amounts of investment in 'fixed automation' equipment and through QC circle activities, which helped automatize material handling and transfer (transport) by means of simple devices. Moreover, some workers tended as many as seventeen machines at Toyota already in the 1950s. Similar practices spread widely in the industry and acquisition of multiple skills by a worker became common practice. In North America and Western Europe, multiskilled workers are today's emerging requirements (cf p. 15) and material handling is still being automated with robots. Prior to robotization, spot welding on the car body had been up to 90 per cent automated in Japan, while Allen reports that the corresponding figure was 60 per cent in North America. In Europe it was often even lower, as Table 2 illustrates.

Consequently, the labour-saving effect of the new technology has been much more limited in Japan than elsewhere (Table 3). The low percentage of robots replacing or substituting for labour at Renault may indicate a relatively high level of mechanization attained in earlier periods of this state-owned company but it may also reflect the concentrated use of the robots in limited areas.

Even within the same country, the amount of labour saving differs from one firm to another for the reasons mentioned above. For example, there is a near
consensus among Japanese industrialists that the average worker–robot replacement ratio is about 0.7 per shift. The company which put it at 0.5 in our survey is known for its highly efficient work organization, and the scope for further labour saving was therefore more limited than elsewhere. A comparative study of two automobile plants in the Federal Republic of Germany attributes inter-plant differences in the labour-saving effect of robots to the previous level of mechanization.8

The labour-saving effect of a given kind of machinery also depends on its rate of utilization. In this connection it is necessary to note that NC machine

Table 2: Robots and the rate of automation of spot welding at selected automobile assembly plants in Western Europe

<table>
<thead>
<tr>
<th>Technique</th>
<th>BMW—Munich</th>
<th>Ford—Dagenham</th>
<th>BL—Longbridge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1982 model change</td>
<td>1982 model change</td>
<td>1980 model change</td>
</tr>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>Manual</td>
<td>50%</td>
<td>10%</td>
<td>68%</td>
</tr>
<tr>
<td>Conventional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>automation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robot</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on Malsch, Dohse and Jürgens (1984, p. 19).

Table 3: The labour-saving effect of robotization in different countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage of robots replacing or substituting for labour</th>
<th>Average gross(^b) no. of workers replaced by a robot in 2 shifts, where it is introduced to replace labour</th>
<th>Requirement of maintenance staff per robot(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>50</td>
<td>1.4</td>
<td>0.2</td>
</tr>
<tr>
<td>United States</td>
<td>Almost 100(^a)</td>
<td>2</td>
<td>1/6–1/10</td>
</tr>
<tr>
<td>Germany, Fed. Rep. of (Hanover VW)</td>
<td>?</td>
<td>2–4</td>
<td>?</td>
</tr>
<tr>
<td>France (Renault)</td>
<td>25–30</td>
<td>4</td>
<td>?</td>
</tr>
<tr>
<td>Italy</td>
<td>Almost 100(^a)</td>
<td>3</td>
<td>?</td>
</tr>
<tr>
<td>Brazil</td>
<td>?</td>
<td>4</td>
<td>?</td>
</tr>
<tr>
<td>Sweden (Volvo)</td>
<td>?</td>
<td>2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

\(^a\)Implicitly assumed in the calculation of the employment impact.

\(^b\)Ignoring new jobs created in maintenance and programming.

\(^c\)Based on only one or a few observations except for the United States.

From various chapters in this volume. The data for the Federal Republic of Germany are quoted in Malsch, Dohse and Jürgens (1984, p. 5). The figures for Sweden were obtained from Volvo when the author visited the company in April 1985.
tools for die-making, prototype production and test production are not always used full time but only when the need arises. Underutilization of equipment, either new or conventional, is common among smaller firms, partly because they tend to keep different types of machines in the same manner as they would keep items in a tool kit (p. 64, Chapter III). The employment impact of these machines would be considerably overestimated if a labour replacement ratio obtained at a plant using them full time was applied to the total numbers of such machines installed in an industry or in an economy. And yet this is exactly what is done in the existing assessments of employment impact of the new technology at the industrial or national level. In fact the problem of underutilization exists even at large plants. For example, Hunt and Hunt (1983) argue that '... as robots become more numerous, the need arises for redundancy in some robot installations. That is already occurring today in body assembly welding applications in the auto industry, where one or two robots at the end of the line are actually spares, available in the event of robot failure'. But this factor has not been taken into account in their projection.

Our study in Japan has unveiled one conceptual problem. When the new technology is applied to do more difficult work than conventional machines used to do, some respondents would say, 'If we had done the current work with older machines, it might have required a number of additional workers'. This kind of statement tends to prompt people to conclude that the new machinery has been saving so much labour. The same is the case with statements concerning relative values of work done with new machines as compared with older ones. As our analysis on small enterprises in Chapter III suggests, the actual number of workers rarely changes in these cases.

(ii) The work-amplifying effect

This effect may be best illustrated by an analogy with the word processor. The much greater efficiency of this machine in modifying a text as compared with a conventional typewriter tends to encourage writers to revise their drafts more often and more meticulously. The implication is that actual savings in labour required for the production of a final document are much more limited than what is expected on the assumption of a constant amount of revision work. Diagrammatically this can be shown as in Figure 1. Lines $0T_0$ and $0T_1$ depict the relationships between $Q$, the amount of text revision work, and $L$, the amount of labour required for such work with a conventional typewriter and a word processor, respectively. Both are assumed to be linear for the sake of simplicity. $0Q_0$ is the amount of revision work the typist used to do when working with a conventional typewriter, $0L_0$ is the amount of labour she put into that work. With a word processor she will finish the same work with labour of $0L_0'$ only. The labour-saving effect of the new machine is $L_0'L_0$. In reality, however, she is likely to be asked to do more corrections to the text once the word processor has been introduced. Thus, the amount of work increases from $Q_0$ to $Q_1$, and the actual amount of labour required for
the work $0L_1$ instead of $0L_0'$. $Q_0Q_1$ is the work-amplifying effect of the new technology, which offsets the labour-saving effect by $L_0'L_1$.

Under the influence of intensifying quality competition, automobile producers have tended to put more work into each vehicle: greater product development efforts (e.g. larger numbers of alternative designs and prototypes), attachment of more numerous and/or sophisticated accessories, shorter product cycles and greater degrees of product differentiation. These are interrelated since, for example, additional R&D work will be required for any of the other changes. The very flexibility of microelectronic machinery encourages this tendency: CAD/CAM and NC machine tools for product development, NC machine tools and robots for machining of differentiated parts and components and for assembly of greater varieties of components and vehicles. These machines have made what was impossible before economically feasible now, as the development and production of some 10,000 varieties of a specific vehicle model by Peugeot (p. 118, Chapter V) demonstrate. Their flexibility (versatility and short lead time) has considerably reduced costs (especially capital but also labour costs) of development and production of less standardized products. However, it has not eliminated such costs. An increased degree of product differentiation gives rise to more developmental and organizational work, and probably also to larger numbers of production lines and workshops not only at the assembler's but also at the component makers' plants, or to more numerous small subcontractors. Even where the new technology has reduced the labour requirements on a given production line or per unit of output (which is not always the case), the labour
saving is therefore offset to a greater or lesser extent depending on how much product sophistication and differentiation increase. This can be shown in Figure 1 by measuring the amount of work required for developmental and organizational work on the vertical axis.

What is interesting is that the enormously enhanced efficiency of the new technology in developmental and organizational work sometimes prompts firms to increase the degree of product differentiation and expand their product development programme even beyond the limit of the existing manpower. In other words, the work-amplifying effect can more than offset the labour-saving effect. This is illustrated by a shift from situation A to D in Figure 1, where labour requirements have grown from 0L₀ to 0L₁'. In Chapter III we suggested that this was one of the main explanations for the recent increase in work hours per vehicle produced in Japan.

It is possible that this effect has been particularly significant in Japan, for a number of reasons. First, as discussed earlier, the labour-saving effect of the new technology there is much more limited (L₀/L₀ is shorter), while its flexibility is more appreciated than in other countries. Consequently, a given amount of extra work tends to give rise to a relatively larger work-amplifying effect. Second, the Japanese manufacturers' interest has recently shifted from highly standardized low-priced cars to more differentiated high value-added cars, partly as a result of the pressure to limit the numbers of vehicles exported. Third, in contrast, in their attempts to regain international competitiveness, North American and West European firms appear to be more anxious to reduce the costs of their cars. This implies that they would be more cautious in augmenting the amount of work per vehicle. Still, the new technology does have the work-amplifying effect: in response to the present author's specific inquiry, a Peugeot representative said it was quite realistic to argue that the new technology tempts firms to increase the average total labour input per vehicle, notably through product differentiation.

(iii) The impact on individual workers

Where net labour savings result from microelectronic innovation, this may or may not cause a practical employment problem. The firm tries to save labour in either of the two following situations. In one case, there is readily available manpower for the job and yet the firm wants to reduce or eliminate manual labour. In the other, it seeks to do so because labour for that job is difficult to secure. Our findings show that the latter is often the case with strenuous or dirty work. In such cases, the job displacement effect of the new technology is little more than a theoretical issue except where there are still some workers to be moved out of the work area. If such workers exist, a need for transfer arises.

How easily a worker can be transferred is a crucial question in determining the employment impact on the existing workers. Even where the labour requirements remain constant, or increase, it is possible for some workers to
lose their job due to the new technology, being replaced by new recruits. Whether and how frequently this happens depends largely on the workers' geographical and occupational mobility.

Whether related to microelectronics or not, technological and organizational changes demand readjustments to workers' occupational and geographical location. At the first Japan–Europe Industrial Symposium (Bedbaek, Denmark, December 1983), the president of the Japan Federation of Metal Workers' Unions (ZENKIN DOMEI) attributed the relatively limited unemployment problem in the process of Japanese technological innovation to 'smooth job reclassifications or reassignments practised in the respective enterprises involved'. Our case study in this country confirms this point. In contrast, the episode of the 50 workers at Peugeot who rejected an offer of a transfer to another workpost (Chapter V) may be recalled as a current example of this problem in Western Europe.11

To some extent this is a question of retraining, so much so that some people argue that the problem of the new technology is not really unemployment but training.12 The Government and automobile companies in France have been spending a large amount of money on training. French firms are also reclassifying jobs to encourage workers' mobility (Chapter V) but there seems to be some problem of workers' receptiveness.13 Our study in the United States points to constraints on inter-occupational mobility caused by industrial relations.

The problem of individual workers' receptiveness to such incentives arises for different reasons. Some are personal. Others are specific to each society. Where it is a common practice for both husband and wife to work, the difficulty in finding job opportunities for both in a new place often explains workers' geographical immobility. This seems to be the case in Sweden, for example. In the United Kingdom, the existing system of public housing is considered to be a major obstacle.14 In some cases, however, workers' immobility is considered to be 'inexplicable', as noted in Chapter V.

From the above, one gains an impression that socio-institutional systems are sometimes not flexible enough for the age of 'flexible automation'. Fortunately or unfortunately, however, the speed of microelectronic production (as opposed to product) technology has been much slower than early authors tended to anticipate, for reasons to be considered below.

4 CONSTRAINTS ON THE DIFFUSION OF MICROELECTRONICS AND PROSPECTS FOR THE FUTURE

The very basic constraint on the diffusion of the new technology is inherent to it. Technical limitations of NC machine tools and robots are spelt out in Chapter II, while their limitations relating to the scale of production are discussed in Chapter I. The country case studies in this volume confirm that in the automobile industry many areas of production remain unaffected by the diversification of demand and product mix and automobile manufacturers try
to maximize opportunities for fixed automation, sometimes as a result of 'commonization' of components for different models. Our findings in Chapter III confirm greater popularity of conventional general-purpose machines and special-purpose machines among smaller firms. This is in conformity with the result of an earlier survey in Japan. In that survey, 46.1 per cent of the large manufacturing enterprises and 40.9 per cent of the small and medium-sized enterprises (fewer than 300 workers) mentioned the incompatibility of the batch size as an obstacle to the introduction of microelectronic equipment. Incompatibility of the quality tolerance was mentioned by 17.8 per cent and 13.9 per cent, respectively.\textsuperscript{15}

One problem peculiar to microelectronic technology relates to the speed of its progress. The rapid rate of its development restrains its diffusion because entrepreneurs anticipate that the microelectronic equipment will become cheaper and more reliable in the near future and take a 'wait and see' attitude (Chapters III and V). This possibility has been pointed out in the United Kingdom as well.\textsuperscript{16}

In addition to these technical constraints, various economic and institutional factors discourage entrepreneurs from introducing microelectronic equipment or make it difficult for them to use it effectively.

All country studies in this volume mention the shortage of maintenance personnel as a major problem. The industries in the United States and West European countries appear to be desperately short of workers of medium-level training and education with 'basic knowledge in a number of fields' (Chapter IV) or workers of 'polyvalence' (Chapter V). This is consistent with findings of a recent comparative study of Britain, France and the Federal Republic of Germany,\textsuperscript{17} which suggest that the lack of adequate manpower is the biggest problem in applying microelectronic production technology. This study is also in line with our Brazilian report in pointing out that the financial burden of investment and the market situation or lack of demand for the work are among the most common problems. Robots' tolerance is very limited with regard to the regularity of quality of the workpieces and considerable amounts of capital investment are often required in earlier production processes. In Chapter III it is noted that for this reason smaller firms are discouraged from using the robot.

Related to this is the need for organizational readjustments, which can be costly (Chapter V). This was also discovered to be the most important constraint in Sweden: 'The experiences from computerised manufacturing management and factory automation are clear. The main barriers and bottlenecks do not stem from hardware and computer software but rather from the organisational structure of manufacturing.'\textsuperscript{18} In France a psychological inhibition against the new technology seems to exist among smaller enterprises, while Brazilian workers are reported to be at a loss when encountering the new technology before becoming thoroughly familiar with conventional equipment (p. 174, Chapter VII).

Despite all these problems, the new technology is bound to be introduced into increasingly wider areas. Microelectronic controlling devices have
already become standard accessories to different types of machinery. By the early 1980s the share of NC machine tools in the total annual investment in machine tools exceeded 30 per cent in major industrialized countries.\textsuperscript{19} The very speed of innovation in microelectronics makes it only realistic to expect the inherent limitations of microelectronic equipment to diminish and many new types of equipment to appear. With the increasing affluence of consumers in industrialized countries the current trend of product diversification will continue, while workers are likely to become even more reluctant to take up strenuous jobs. Indeed, entrepreneurs we interviewed in Japan and Western Europe alike mentioned this as a factor which obliged them to increase the use of new automation technology. There is a consensus of opinion that the major areas left for automation are the final assembly and offices.

The impact on employment in the future is likely to depend largely on two factors: the proportion of NC machines and robots used in a system (e.g. FMS) as opposed to stand-alone machines and the extent of the work-amplifying effect. Our findings in Japan suggest that machinery used in a system creates a greater labour-saving effect. Another important influencing factor will be the rate of utilization of these machines. While increased supplies of easier-to-handle, lower cost machines will accelerate their diffusion, it may also reduce the users' eagerness for maintaining a high rate of their utilization, and consequently their employment impact.

In Western Europe and North America, however, organizational rationalization may create a much greater employment impact than microelectronic innovation for some time to come. No less important will be the increasing competition from newly industrializing countries such as the Republic of Korea and Yugoslavia.\textsuperscript{20} In so far as the Japanese automobile industry is concerned, the most serious threat to employment opportunities may come from the internationalization of its operation, namely overseas investment.

5 EMERGING ISSUES

We suggested above that the existing literature tends to overestimate the labour displacement effect of the new technology partly because it neglects the work-amplifying effect of such technology. Since this effect can be expected from not only microelectronic but also any other kind of labour-saving technology, it deserves serious empirical investigation.

Our findings in Chapter III do confirm that smaller enterprises use microelectronic equipment somewhat differently—often less systematically—as compared with major firms. We noted earlier that this can be another important explanation for the overestimation of the negative employment effect of the new technology, since the existing assessments of such effect usually neglect it. Our studies included in this volume are not free from this problem. For a more realistic assessment, a more extensive research focused on smaller firms is necessary.

Our findings in earlier chapters show that the socio-institutional framework of industries is sometimes too rigid for the age of rapid technological
development. Attempts to change the situation are not lacking. For example, Chapter IV refers to GM's Saturn project. The author of that chapter is not very optimistic about the outcome of such efforts, however. Obviously here is an important area of further research.

Somewhat related to this is the question of geographical and inter-occupational immobility of labour. The cause of this problem varies from case to case, and it is obviously not just a matter of economic incentives. It merits a great deal more research, as one press report recently argued: 'Every person in charge of the matter knows that in France there is often an inexplicable bottleneck' (our emphasis), when one tries to transfer employees.

So far, surplus labour has been absorbed by means of natural wastage (non-recruitment of new workers), early retirement, shortening of yearly work hours and encouragement of repatriation of immigrant workers (France and the Federal Republic of Germany). In Western Europe, adjustments in yearly work hours have been used by individual firms or plants (e.g. chomage technique in France) as a means to adapt to market fluctuation. The effectiveness of this solution to a longer-term unemployment problem, however, remains unexplored.

Regarding Third World countries, the Brazilian study in this volume raises an important policy issue. In order to maintain the international competitiveness of the automobile industry and secure immediate job opportunities and foreign exchange earnings, concessions for the import of new equipment are necessary. This, however, constrains the development of the local capital goods industry. The problem is compounded by the fact that all the assemblers and major component producers/exporters are foreign firms. The situation is similar in other countries such as Mexico. On the other hand, the Republic of Korea appears to have been more successful in developing an indigenous industrial base by limiting the participation of foreign capital. What is especially interesting in our context is that microelectronics has apparently been helping to reduce or circumvent the problem of the technological gap vis-à-vis more highly industrialized countries. Her experience hints that even in high-technology industries developing countries need not be at the mercy of multinational enterprises, as many authors tend to argue. But what explains the difference between Brazil and the Republic of Korea? This should be a subject of study that is relevant to many Third World countries.

NOTES

1 The total numbers of FMSs installed in 1984–85 have been estimated at 100 in Japan, 47 in the United States, 25–35 in the Federal Republic of Germany, 25 in Italy and the Netherlands and 17 in France (UN ECE, 1986, pp. 25–6). Of a total of 60–70 FMSs existing in West European countries, 20 per cent were believed to belong to light automotive industries (cars and motor cycles) and another 14 per cent to heavy automotive industries (tractors and trucks) (UN ECE, 1986, pp. 31 and 52). This implies that the total number in the West European automobile industries was fewer than 25.
A Synthesis of Findings

2 This phenomenon is not confined to the automobile industry but also prevails in other industries. See OECD (1983) and UN ECE (1985).

3 An extremely interesting question is to what extent the western industrialists' attitude will change in the direction Seering anticipates.


5 Hunt and Hunt (1983), p. 67. In General Motors' Saturn project, however, flexibility is considered to be one of the key ingredients (cf Hegland, 1984, p. 60).

6 The proportion of non-automobile business in the total turnover of North American automobile companies declined rather than increased (note 8, Chapter IV).


8 Windolf (1985).

9 In this connection, it is important to remember that in 1983 factories with fewer than 100 workers accounted for 30 per cent of total NC metal-cutting machines, 50 per cent of metal-forming machines and 22 per cent of robots installed in the United States (American Machinist, 1983). In Japan, one-fourth of the total NC metal-cutting machines shipped to the home market have been destined for enterprises with fewer than 30 workers (JMTBA). In Italy, 33 per cent of machining centres and 21 per cent of NC lathes belonged to enterprises with 20-49 workers in 1975 (UCIMU, 1975, Table 19a).


11 Peugeot's case is far from exceptional. See Figaro, 22 November 1984.


17 Northcott et al. (1985), p. 73. See also Japanese Government, Chūshō Kigyō-chō for 1981, p. 184 for similar findings.

18 Selg and Carlsson (1980).


20 Cf Nihon Keizai Shim bun (Tokyo), 6 September 1985 (evening). A similar view has been expressed by Sadler (1980), who argues that 'the threat to employment opportunities from the new technology in Europe may even today be in danger of being overemphasised. I believe that a greater danger is posed by increasing industrialisation in other (less developed) parts of the world' (p. 295). He believes that technology is useful in answering this threat. Sometimes, however, late-comers can be free of constraints in applying the new technology more vigorously.

21 The new agreement provides, among other things, for 'permanent job security' (or no lay-off 'except in case of unforeseen or catastrophic events or severe economic conditions') for no fewer than 80 per cent of the workers, for replacement of hourly rates by salaries and for performance and attendance bonuses and sharing of profits increases generated by the QC circle activities (News from the UAW, press release, 26 July 1985).


24 Hyundai of the Republic of Korea is now emerging rapidly in the international automobile market, especially in Canada. The Korean success is partly attributable to the fact that they are free from the 'voluntary export restriction' in the United States and Canada and benefit from the Special Preferential Tariff Concession. This company combines design technology of Italy, production technology of the United States, Japan and some other countries, and the Japanese management technique transferred by Mitsubishi since 1975 (Amsden and Kim, 1985, p. 10).
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