NEW PRODUCTION CONCEPTS *

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Flexibilty within a framework of internal labour markets is now widely seen to be an important factor in the ability of manufacturing firms to respond quickly to changes in market conditions — which is increasingly coming to be the form that competitive advantage takes in advanced industrial economies. An emerging and flourishing literature has identified a number of 'new production concepts' being developed in manufacturing industries, that depart from time-honoured Taylorist systems of job fragmentation and skill minimisation. The new concepts, such as 'flexible specialisation', 'human-centred production', and 'diversified quality production', are all in one way or another seeking to characterise a form of 'functional flexibility', that both enhances productivity and offers workers themselves a greater sense of involvement with their activity. The new concepts rest on the identification of a critical linkage between work organisation, skill formation and advanced manufacturing technology; they point to a convergence between the previously separate worlds of work and of learning.

In this paper the new production concepts are characterised as elements of an emergent 'post Fordist' technoeconomic paradigm. The present period of uncertainty can be construed as a transition between the Fordist paradigm centred on mass production, and its successors. There is nothing predetermined about the shape of these successors: this will be the outcome of a prolonged economic, industrial and political process as much as of a technical process. The choices are identified as falling between a continuation and intensification of Fordism, dubbed Computer-Aided Taylorisation; or a break with Fordism, dubbed Skill-Dependent Innovation. The new production concepts are characterised as instances of the latter approach to manufacturing management and technology. It is through this notion of 'competing paradigms' that this paper formulates an approach to the 'politics' of technological change.

Keywords: New technology, new production concepts, productivity, flexible specialisation, human-centred production, skill formation, work organisation.

INTRODUCTION

It is now widely agreed that the industrial and production systems that powered the 'post-war boom' are undergoing substantial transformations. The macroeconomic framework within which goods

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and services are produced has been at issue at least since the onset of recession in the 1970s, while at the microeconomic level there are fundamental changes occurring in technology, work organisation and skills formation structures. Competitive advantage is moving from a low-cost market orientation to one based on quality and targeting of market niches.[1]

The dominant organisation or theoretical framework characterising the various processes of manufacturing industry this century, has been that of 'mass production'. The conceptual array associated with this paradigm is familiar: it includes notions of flow and large batch production; infrequent changes of model or die; cost minimisation through standardisation; labour standardisation and simplification through time and motion study; and returns to scale achieved by expanding production runs relative to given overheads. The competitive strength of the mass production paradigm, and the reason for its rise to dominance over an alternative paradigm of customised, craft production, lay in the opportunity it created to break down complex tasks into simpler components for which less-skilled labour could be employed. The extra overheads, in the form of costs of design and supervision, would be more than balanced by the returns to scale if production runs could be made long enough. These 'principles' of production efficiency based on division of labour were first spelt out clearly by the UK mathematician and political economist Charles Babbage, in his 1832 text *On the Economy of Machinery and Manufactures*, before mass production had arrived to bear him out:

> That the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of the operations into which the art is divided.[2]

The origins, competitive strengths, and limitations of the mass production paradigm are by now reasonably well studied and understood. Whereas in the 1950s and 1960s the 'path to prosperity' seemed to lie unquestionably along mass production lines, this is no longer the case in the 1980s and will be even less so in the 1990s. Familiar assumptions and practices are having to give way in the face of new competitive pressures, new technologies, and new systems of management and organisation.

Against this background, an array of 'new production concepts' has emerged, which could impart a new logic to the process of production. This logic is at variance with the familiar principles of mass production. It is to the exploration of these new production concepts, and the links between them, that this paper is addressed.

We shall utilise the notion of a 'technological paradigm' to characterise the previously dominant mass production system, and to sketch the elements of a range of successors to it. Our point of departure is that there is no 'technologically determined' trajectory involved here, but instead a range of alternatives which will compete socially, politically and in the marketplace. In this way we shall attempt to shed light on the notion of a 'politics' of technological change, in the context of a fundamental transition between 'competing paradigms'.

THE RISE AND FALL OF MASS PRODUCTION

The origins of mass production lie in the 'American System' of production of interchangeable and standardised parts, that so shocked and fascinated European observers in the mid 19th century.[3] Its development can then be traced through the following steps: the rise and consolidation of corporations which provided an 'internal' planning and administrative mechanism that took over from market-mediated links between small suppliers;[4] the rise of a separate profession of management, and its intervention at the level of the labour process through 'time and motion' study, first practised in any systematic way by Frederick Winslow Taylor;[5] and finally the development of the moving conveyor, or 'assembly line', which provided the technical means through which the productivity potential of Taylor's principles could be reaped.[6]

Scholars are agreed that the mass production system became an economic force in the US during the First World War, and was then consolidated in the US and Europe in the interwar years, spreading to the entire industrialised world, West and East, in the post-war period of 'boom'. Piore and Sabel argue that its rise to dominance constituted an 'industrial divide' that separates the mass production system from previous customised production systems — systems which were put in the shade, but never eliminated, by their rival.[7]

The success of mass production is now understood to depend on a complex of factors which extend well beyond the technical concerns of the system's time and motion architects. Chief amongst these is the creation and maintenance of mass markets where mass produced goods may be bought, and the maintenance of mass purchasing power through high wages and social welfare systems. This meant recognition of mass industrial unions by employers, and recognition of the role of governments in maintaining conditions of economic buoyancy through Keynesian macro economic management.

The structural underpinnings of the mass production system have been elucidated by a group of analysts who have come to be known as the 'French regulation school'. These theorists identify three aspects of the paradigm of mass production. These are: its *technological* model, resting on a rigorous standardisation of operating methods and corresponding separation between conception (design, organisation and methods) and execution on the factory floor; its regime of *accumulation,* which counterbalanced the explosive growth in productivity unleashed by mass production with an equally massive growth in consumption, financed both by wages and by increasing levels of public expenditure; and its mode of *regulation*, which replaced a system of competitive adjustment and frequent trade cycles, with an integrated framework of collective bargaining, large firm market dominance, macroeconomic management by government, and at the international level a stable financial and commercial environment favouring trade and capital flows. This ensemble of relations is termed the 'Fordist system'.[8]

Empirical evidence from the 1970s, and increasingly in the 1980s, indicates that all is not well with the mass production system. In its heartland, the US, the decline of manufacturing has been widely documented.[9] Productivity growth has failed to match that of its major competitors, such as Japan. One industry after another has found itself fighting against lower cost and sometimes higher quality imports, leading to the disappearance of whole industrial sectors. New mass production industries have been established in the Far East, particularly in Taiwan, Hong Kong, Singapore and South Korea.

At one level of analysis, the decline of competitive strength in the mass production heartlands has been attributed to 'external' shocks such as the rise of OPEC and the oil price rises of 1973 and 1978; or to misguided government and industry policies, rigid industrial relations, and to weakened R & D efforts.[10] While these factors may have contributed to the timing of the decline, it would be seriously misleading not to look further for causes, in the system of work organisation and management practices that have grown up under the umbrella of mass production. It is these factors which are tackled by authors such as Wickham Skinner, with his notion of the 'productivity paradox', and Hayes and Wheelwright, with their concept of 'sustainable competitive advantage'.[11] Their analysis decisively corroborates, at a practical and down-to-earth level, the rather more abstract analysis of the French regulation school.

Skinner points to the frustration experienced by firms which have sought to improve productivity in the face of new competitive pressures by *intensifying* their previous practices, particularly in the cutting of labour costs. After conducting a survey in the early 1980s in a number of US companies, he found that they looked for productivity gains through cost reductions, rather than through long-term strategic planning and development of human resources. Similarly, Hayes and Wheelwright, in their influential text *Restoring our competitive edge: competing through manufacturing* (1984), focus on what they call the 'internal causes of the slowing of industrial competitiveness in the US'.

In discussing strategies of innovation, Hayes and Wheelwright pinpoint the real reasons for the decline of US manufacturing in the management practices that have been nourished in the soil of Taylorism. US firms have tended to rely, they argue, on 'great leaps forward' rather than on incremental advance; this favours a perspective that sees reliance on the skills of the workforce as dangerous, and efforts to train and upgrade skills as being a waste of resources. Hard-nosed, 'low-trust' personnel policies are self-defeating, they argue, when the technologies required to stay competitive become more demanding.[12] In stark contrast, the 'incremental approach' places a premium on long-term commitment and planning. In such a case, the company expects most of its improvements to bubble up from lower levels in the organisation. Thus what appears to be a neutral choice, as between a stepwise and an incremental approach, turns out on closer examination to have fundamental implications for work organisation and employee relations, and through these, for productivity.

Further evidence of decline is found in the range of strategies firms have adopted in their attempts to extricate themselves from crisis. In his text *Work and Politics*, Charles Sabel identifies some of the options, such as the strategy of intensified application of mass production principles — expanding outwards, on a world scale (outsourcing, capital flight); contracting inwards, behind heavy protectionist measures; or rationalising and reorganising production, along familiar Taylorist lines, utilising computerised equipment. These strategies certainly offer some relief from the rigidities and pressures induced by the global spread of mass production networks — but they quickly come up against their own internal limits, in the form of further rigidities and lack of capacity to innovate and diversify. A second strategy adopted by firms in the 1970s and 80s involves moving away from mass production towards specialty production, looking for market niches in the world economy — but seeking to keep intact the work organisation and industrial relations practices developed in the heyday of mass production. Again, these strategies come up against the limits of the Fordist base on which they are erected.[13] Product innovation and specialisation place a premium on a highly skilled and motivated workforce — but this level of commitment is incompatible with Taylorist principles of work organisation development for mass production.

NEW PRODUCTION SYSTEMS

An alternative response to the competitive pressures that are straining the mass production system, is for firms to restructure their production around new axes: flexibility in place of mass production; and skilled worker input that reintegrates a degree of conception with execution, in place of continued job fragmentation.

One development that has helped to trigger these responses is that of computerisation based on microelectronics. The building into machines of information collecting and processing power, in both traditional industrial sectors and in white collar clerical, financial and retail sectors, has set new challenges to the design of productive and efficient systems of work organisation. Process applications of microelectronics — such as in CNC machines, CAD-CAM equipment, Flexible Manufacturing Systems; and in the white collar sector: Electronic Data Interchange; computerised typesetting systems; computerised travel booking systems; computerised telecommunication exchanges, and so on — have revealed in stark form that enormous increases in *productivity* are available, based on *flexibility* of operation, which in turn is based on the *programmability* of the equipment. Changes in operation (such as new batches of parts, or new prices and timetables, or new typefaces) can be achieved through manipulation of software, rather than through changes in hardware.[14] However, study after study reveals that these productivity gains are *not* being achieved by firms which introduce and utilise the new production systems along lines familiar from the paradigm of mass production.[15]

With CNC equipment and FMS installations, for example, it is observed that US firms have not achieved anything like the productivity gains available, whereas Japanese firms have exploited their flexibility to the full.

Jaikumar cites the case of one prominent mid-western heavy equipment producer who installed an FMS to make just eight different parts with a total volume of 5,000 parts per year:

> Once the FMS went on line, management made few improvements by discouraging any changes. The FMS boosted machine uptime and productivity, but it did not come close to realising its full, and distinctive, strategic promise. The technology was applied in a way that ignored its high potential for flexibility and for generating organisational learning.[16]

These failures are linked to work organisation strategies that adhere to the view that sophisticated machinery can be operated optimally by unskilled staff. In NC, and now in CNC machining, this approach has repeatedly led to productive confusion and loss of competitive position.[17] Conversely, an approach to the utilisation of CNC equipment and FMS installations that builds on the input of skilled workers, is found to generate maximum productivity levels.[18]

In CAD systems, there has been a tendency to design and install systems according to Taylorist principles of job design, based on the expectation that productivity would be enhanced by simplifying design procedures, and building in electronic surveillance of the design staff. Again, such expectations are frustrated by the experience, which indicates that repeat work is minimised, and a 'match' between design and manufacturing capability is best achieved, when the CAD systems are allowed to *complement* the skills of designers and draftsmen, rather than seek to replace them.[19]

In white collar applications, a similar process of realisation has been at work. In banking and the finance sector, computer applications have transformed a previously conservative and stable business structure. Early attempts to install Electronic Data Processing systems along familiar Taylorist lines led to near catastrophe, as errors input into systems by unskilled operators propagated through the financial networks. Banks learned from this that on-line systems call for a new type of abstract, system-comprehensive skill on the part of tellers and clerical staff.[20]

This range of experience with new production systems has led observers to generalise the new set of skill dependent management and organisation strategies as 'new production concepts'. It is to these that we now turn, against the background of a crisis in mass production when exposed to new competitive pressures and confronted by the new, programmable technologies.

NEW PRODUCTION CONCEPTS

We can trace the use of the phrase 'new production concepts' to the work of the German industrial sociologists, Horst Kern and Michael Schumann, in their influential text *End of the Division of Labour?* (1984).[21] They argued that German industry, in certain core sectors where new computerised production systems were being installed, was developing a 'manufacturing strategy' that we have characterised above as one of skill dependence. This strategy placed explicit heavy reliance on the contribution of skilled labour to achieving productivity gains inherent in the new technology, reversing the direction of previous strategies inspired by principles of Taylorism.

Kern and Schumann formulated their hypothesis on the basis of empirical surveys carried out in several industries — the motor, chemical and machine tool sectors, and with less emphasis, the food-producing and shipbuilding industries. They looked at these in the mid 1960s, and again in the early 1980s; they noticed a striking difference in the organisational strategy being pursued by firms at these two periods. In their 1970s text, they adhered to a notion of deskilling as a dominant employer strategy; in their 1984 text they advanced the view that a major turnaround was in train.

In relation to the motor industry, for example, Kern and Schumann cited memoranda written by executives that spelt out in detail why firms should depart from a strategy of dividing tasks and separating responsibility from job execution. They argued that this trend amounts to a 'reprofessionalisation' of production work; they link it with an explicit market strategy that firms are adopting, oriented towards enhancing the quality and diversity of products.[22]

Kern and Schumann emphasised the point that this reversal of management strategy was not in any way derived from 'humanist' concerns to enhance the 'Quality of work life' of operators, but from hard-headed calculations concerning the most profitable and productive method of organising production. They characterised the adoption of the 'new production concepts' as an employer choise, and not in any sense one which was imposed on employers by German unions.

Flexible specialisation

At a rather broader level of analysis, Michael Piore and Charles Sabel have developed a similar notion in their text *The Second Industrial Divide* (1984). Starting from an analysis of the problems of mass production industries, Piore and Sabel outline what they see as alternative strategies adopted by firms. These have taken the form of an intensification of mass production principles; or a modification of these principles in favour of innovation and specialisation utilising new technologies; or a complete departure from such principles in favour of a strategy of 'flexible specialisation'. Such a departure, they argue, is evident in the strategies of firms which seek flexible market response combined with polyvalent skills of 'craftsmen'-like workers: it amounts to an 'industrial divide' comparable to the splitting away of mass production from 19th century craft traditions in the early 20th century.[23]

From the perspective of the limits being reached by the industrial paradigm based on mass production, Piore and Sabel advance the concept of flexible specialisation as an alternative and viable system of organising production. Theirs is a far-reaching, all-embracing critique of prevailing forms of manufacturing management and economic regulation.

Piore and Sabel locate the seeds of a viable alternative in the traditions of craft production that have always co-existed alongside mass production industries. They argue that the key to a craftsman's skill lay not merely in the possession of a sequence of specialised procedures, but in the ability to take on a novel job and respond with an appropriate set of tools and techniques; it is the *flexibility* of response that is the secret of superiority of specialised craft production. For Piore and Sabel, it is this aspect of work which will be called on in future by operators of computerised equipment — leading to a radical break with Fordist methods of work organisation. They state:

> Flexible specialisation is a strategy of permanent innovation: accommodation to ceaseless change, rather than an effort to control it. This strategy is based on flexible—multiuse—equipment; skilled workers; and the creation, through politics, of an industrial community that restricts the forms of competition to those favouring innovation. For these reasons, the spread of flexible specialisation amounts to a revival of craft forms of production that were emarginated at the first industrial divide.[24]

They give as an instance of a flexible specialisation strategy in operation, the networks of technologically sophisticated, flexible small manufacturing firms in central and north western Italy. The claims of Piore and Sabel, while controversial, have been extremely influential in the 1980s.

Diversified quality production

As an extension or elaboration of the notion of flexible specialisation, the German sociologists Arndt Sorge and Wolfgang Streeck have introduced a further category of 'diversified quality production'. They argue that 'microelectronic circuitry has progressively eroded, in the course of the past decade, the traditional distinction between mass and specialist production . . . The result is a restructuring of mass production in the mould of customised production.'[25] Sorge and Streeck identify four distinct 'production strategies', organised around the distinctions between high and low volume production, and between standardised price-competitive production and customised quality-competitive production. They argue that the term 'flexible specialisation' is now too closely identified with the idea of small independent craft production to be applied usefully to high volume production.

Human-centred design criteria

At the level of the design process, the trend towards development of new production concepts is captured in the explicit formulation of 'human-centredness' as a design criterion for FMS installations and other computerised, programmable systems. The concept can be traced principally to the work of the UK engineers Dr Mike Cooley and Professor Howard Rosenbrock. Cooley stated in his 1980 text *Architect or Bee*:

> The human-centred system will be more *efficient* than conventional fully automated systems because the operator can use his skills and experience, with the aid of powerful software tools, to optimise the machining programs and the job scheduling in the cell. It will be more *flexible* because any job that the machines can cope with can be machined in batch sizes of one upwards. It will be more *robust* because there is much less dedicated automation and electromechanical complexity . . . It will be more *economical* because it is designed to be more efficient, more flexible, have a higher uptake, lower running costs, cost less to buy and take less time to commission.[26]

Early attempts to implement the concept on a cell at UMIST were not successful, but progress is now being achieved at a variety of sites in Europe under the EEC Esprit program 'Human Centred CIM Systems', together with trials at major firms such as BICC and Rolls Royce.[27] The technical literature is also coming to give greater recognition to the notion of 'human-centredness' and the means available to operationalise the concept.[28]

TAKE-UP OF NEW PRODUCTION CONCEPTS AND ALTERNATIVES

It is one thing to formulate new concepts for the organisation of production and for engineering design — but it is another thing to see them implemented. To what extent are the 'new production concepts' being taken up by firms, and what are the major alternatives competing with them.

The German automotive industry has been an important test case for the new manufacturing strategy. Recent studies by the OECD, and by

Juergens *et al.* from the WZB, Berlin, indicate that the motor industry has reversed its previous policy of introducing 'unmanned automation', and is now swinging behind a new policy where programmable tools are operated by skilled workers frequently formed into groups.[29] At Volkswagen, for example, there has been significant job reorganisation, enlarging job functions and responsibilities. New production categories such as 'stationary press line operator' (*Strassenfuehrer*) and 'monitor of complex equipment' (*Anlagenfuehrer*) have emerged in relation to computer-aided equipment. Wage systems have been changed to facilitate the new emphasis on enlarged work and team work. The changes have been carried through on a basis of codetermination with Works Councils and the industry union, I G Metall.[30] Similar changes have been observed at car producers BMW, Audi and Ford in Germany.[31]

In Sweden similar changes can be observed at the plants recently established by Volvo. The plant established at Kalmar in 1974, where the assembly line was dispensed with for the first time in the modern automotive industry, has become justly celebrated. But the pressure and electronic surveillance of work, and the divisions of responsibilities even within work teams, meant that this plant could not be taken as a clear departure from Taylorist principles.[32]

Volvo reportedly intends to go much further in its latest assembly plant, at Uddevalla. In 1986 a pilot training workshop was established to prepare for the plant, charged with the task of designing the most effective model of work organisation. In October 1987 a high ranking ACTU delegation from Australia visited Volvo Uddevalla, and reported on the plans in their report, *Australia Reconstructed*, as follows:

> There is no standard production line. Instead, work teams consisting of groups of multi-skilled workers capable of handling all operations will work within U-shaped production bays. Flat hierarchies, job rotation, integrated materials handling and work stations will provide the organisational framework for assembly. High levels of quality assurance and zero rejection rates will be a common objective of workforce, management and unions.
>
> The new plant will take the form of six small factories grouped around a centre from which components will flow to the factories. Each factory will have four teams consisting of between eight and twelve workers who will build complete cars. There will be only three management levels: the management board including the production director; the six factory or plant directors; and team supervisors.[33]

At the time of writing, no statement confirming these plans has been issued by Volvo or the unions. But if the description given to the ACTU Mission is accurate, then Uddevalla represents a decisive break with the principles of Fordism, and a final abandonment of the mechanical notion of a moving assembly line. Building completed cars, with components supplied by the most advanced computer-assisted inventory system, is clearly seen by this manufacturer as the way forward.

In the meantime, Volvo Components Corporation is building a major new engine plant at Skovde, in Sweden. Advanced FMS technology is being installed.[34] Even more innovative is the work organisation proposed. Based on a personal visit to the plant in August 1988, the proposals can be described as follows.

Each FMS, or 'line' as Volvo calls it, produces an engine component, such as cylinder blocks, valves or camshafts. Machining is carried out by CNC centres linked by Automatic guided vehicles (AGVs) and Volvo-designed overhead parts handling ('gantry robots') equipment. Under programmed control, the parts are moved from one machining centre to another, where different operations are performed. All programs are contained in discs or tapes resident in the machining centres: there is no separate, centralised 'control centre'. Different versions of components can be produced flexibly by change of program. Each FMS is operated by a team of three or four highly skilled workers (a majority of whom were women, on the day I visited). The multi-skilled team members are in total control: they can at any time interrupt a programmed sequence, or reschedule operations, by typing commands into their consoles. They need never lay hands on an engine component.

In the final engine assembly area, teams of nine to ten workers will follow an engine through from initial assembly of components, to final testing of the completed engine. Tasks will be performed at different work stations, while the engines-in-transit will carry all the components needed for assembly in 'supermarket' baskets attached to AGVs. A member of the team will test the engine in an area insulated from the assembly room, and will be able to make adjustments on the spot at a specially designated rectification work station.

This innovative system of job and work design meets a number of criteria which may be advanced as defining post-Fordist work organisation:

- The assembly process is completely integrated, with individual workers being responsible for an asssembly job from start to final approval;
- workers have broad levels of responsibility, and exercise considerable discretion in the fulfilment of their duties, for which they are highly trained;
- all work is team-based, with the team being responsible for allocating tasks amongst its own members;
- co-ordination of tasks is exercised internally, within the team, rather than by an external supervisor, with several teams being responsible to an overall plant manager, and no intermediary management levels getting in the way.[35]

In Japan, the productivity potential of CNC equipment has been taken up in a vigorous fashion. Previous attempts to explain Japanese manufacturing efficiency in terms of supposed 'cultural factors', or through the influence of institutions such as 'Quality Circles', have been discredited.[36] It is now agreed in the informed literature that Japanese efficiency in the use of computerised equipment is based on a similar efficiency achieved in previous production systems, of which the exemplar is the 'Toyota Production System'. In this, techniques such as JIT, TQC and SMED are integrated into a holistic approach to meeting the 'manufacturing challenge'.

But these Japanese innovations cannot be said to constitute a distinct break with Fordism and Taylorism. They constitute an intermediate category that we might christen as 'Toyotism'.[37] The emphasis on highly-skilled, autonomous workers is certainly a crucial ingredient, and the training of human resources is regarded by firms as an investment rather than a cost. But there are overtones of Taylorism in the organisation of work, in the greater pressures brought to bear on workers with JIT, and in the explicit deskilling tendencies manifested in speeded up die exchange operations (SMED).[38]

In Australia, several firms have taken the initiative in introducing new styles of manufacturing management. For example, Ford Australia has developed a new form of participative management (dubbed the 'Process Intent' approach) which has been put to the test in the design and development of a new model, the EA26, produced totally in Australia. This program was managed through group processes organised in System Control Groups and Design Teams. Ford Australia is in the process of abandoning former Taylorist assumptions, both in design and production, and the quality and productivity gains have been impressive.[39] In the steel industry, BHP Steel Coated Products Division mill at Westernport, Victoria, has developed an imaginative approach to job redesign, skill formation career paths, and training, all linked to a new wages system, to underpin its plans for restructuring and competitive survival in the 1990s.[40]

At the sector and national level, Australian industry has embarked on a fundamental restructuring of its industrial relations system, through a series of agreements negotiated under the 'Second Tier' of the national wages system, and since August 1988, under the 'Structural Efficiency' principle of the new wage fixing guidelines. These agreements promise to place Australian industry on a new competitive footing; insofar as they establish new broadened job categories, skill formation structures and career paths for workers, they represent a fundamental departure from the previous 'Fordist' industrial relations and wages system.[41]

In the UK, on the other hand, manufacturing revival seems to be pinned to the success of organisational innovations that have been characterised as '*functional flexibility*' and the '*flexible firm*'.[42] In this model, a multi-skilled 'core' group of employees offers flexible operations by crossing traditional boundaries, while a 'periphery' of part-time or sub-contract workers offers 'numerical flexibility'. Such a strategy constitutes a departure from Taylorism for the 'core', but stops well short of any form of codetermination with these skilled workers, while for the periphery it constitutes an abandonment of social responsibilities.

There is thus a wide variety of institutional and organisational responses to the challenge facing firms of maintaining a sustainable competitive advantage through the use of advanced manufacturing technology. While the 'new production concepts' point in a direction which in many ways reverses the widely respected principles of Taylorism, there are *alternative* firm — and sector — principles which seek to *intensify* Taylorist principles with the aid of computerisation. There are responses that seek to eliminate skilled labour input through automation, and to reduce the firm's dependence on its human resources through contracting-out most of the skilled work.[43]

Let us be explicit as to this choice of direction. One line of development extends the time-honoured principles of job fragmentation, standardisation of routines, and transfer of intellectual functions to software, leaving as little discretion as possible to operators. This is a route I propose we call *'Computer Aided Taylorisation'*.

The other is a strategy that departs from principles of work organisation inherited from the heyday of mass production, and instead aims to maximise productivity by maximising flexibility of operation, which in turn requires commitment to a system of worker autonomy and skilled decision-making, interacting with information provided by computer systems as *aids to decision-making* rather than as instructions or demands for data. I propose that we call this strategy one of *Skill Dependent Innovation* (SDI).[44]

THE POLITICS OF PARADIGM SHIFTS IN PRODUCTION TECHNOLOGY

The future for the 'new production concepts' is uncertain — of that much we can, at least, be certain. It is an uncertain future for the fundamental reason that the course of technological change is not determined. It is a social process in itself which is responsive to a variety of influences at different levels — from the technical level where questions of efficiency and optimal operation predominate, through the levels of sectoral co-ordination and national economic regulation, identified above as crucial components of the twentieth century Fordist system based on mass production. Piore and Sabel put this anti-determinist position well when they state:

> Industrial technology does not grow out of a self-contained logic of scientific or technical necessity: which technologies develop and which languish depends crucially on the structure of the markets for the technologies' products; and the structure of the markets depends on such fundamentally political circumstances as rights to property and the distribution of wealth. Machines are as much a mirror as the motor of social development.[45]

For them, the 'first industrial divide' was explicitly a 'choice of technology' effected at the turn of the century by major firms as a social and political act. It reflected a reading of economic conditions, but it was not determined by those conditions. Others have taken this notion further, and have described the inter-related series of choices that linked mass production with the rise of oil as the principal source of energy and the development of macroeconomic regulatory techniques, as constituting a 'technoeconomic paradigm', identified as a Fourth Kondratiev Wave.[46] In her 1985 paper on 'microelectronics, long waves and world structural change', Perez summarises this point of view as:

> 'The present period is seen as one such transition (from one technological regime to another). The mode of growth that led to the boom of the 1950s and 1960s has run its course. The world arrangements, shaped by the characteristics — and fostering the full deployment — of a constellation of mass production technologies based on low-cost oil, to another capable of fruitful and appropriate interaction with a new system of flexible technologies, based on low-cost electronics.'[47]

Once the paradigm takes shape, it constrains all further choices. This is why the present period of uncertainty, when the shape of the post-mass production industrial order is not yet determined, is of such critical significance.

This is where the French regulation school analysis has its pertinence. It indicates that the difficulties faced by manufacturing industry will only be overcome when an equally comprehensive post-Fordist paradigm takes shape, encompassing a threefold technological model, regime of accumulation and mode of regulation.[48] In the language of the Kondratiev wave theorists, the 1970s and 1980s have witnessed the beginnings (upswing) of a new wave based on microelectronics, as well as biotechnologies and new materials. Perez is at pains to point to the range of new socio-institutional innovations that are needed to assure the 'assimilation' of the new technologies to the economic and social systems. It is in this context that the 'new production concepts' make sense.

A 'choice' between technologies, and by extension, between technoeconomic paradigms, is inevitably a social and political, rather than a purely technical, process. A school of thought has sought to generalise this notion, turning it into an abstract principle of the 'social construction of technologies'.[49] While this school has met with a critical success, and its members have illuminated the process of technological change from the development of Portuguese ships in the 16th century to that of guided ballistic missiles in the 20th, it is striking how the principal proponents of the school take their examples from all spheres of life *except* the workplace.

Yet it is within the sphere of manufacturing technology that the social factors involved in the determination of technological change are most apparent. A clear example is provided by the emergence of the SMED technique. In this case, it is the pressure on firms to enhance flexibility that forces them to identify one of the key 'hidden' underpinnings of long 'mass production' runs, viz. long set-up times. When this is tackled as a design problem in itself, a number of solutions present themselves;

even CNC machine advertisements now make a point of the low set-up times that can be achieved with them. In this way, a major 'structural' component of the paradigm of mass production, is removed — opening the way to technical alternatives.

But it needs to be emphasised further that a *choice* of technology, or of technoeconomic paradigm, must lead to the attempt to *impose* this choice by interested parties through whatever political and social channels are available to them. This is a point on which the SCOT school is strangely silent. In the philosophy of science, the notion of scientific 'paradigm' is taken to be a set of rules or theoretical framework that changes with time. While the debates between competing paradigms can be conducted with a certain passion, there is an element of passivity in the notion of scientific paradigm shift — it 'happens', as it were, behind the backs of the players.[50] When the notion of paradigm is imported into the realm of technology, and particularly into the 20th century workplace with its seething commercial and industrial pressures, this 'passive' quality quickly gives way to recognition of the need for *open advocacy* of a new direction or paradigm shift *as a political act in itself*.

We thus succeed in formulating a clear notion of the *politics* of technological change, in terms of the resolution of the claims of 'competing paradigms', and the interests of the parties which promote the different paradigms. This represents an advance on characterisations of the process of technological change, such as those based on notions like 'technophobia' and 'technophilia'.[51] The advance represented by the notion of 'competing paradigms' is that the antagonists do not have to be seen as 'pro' or 'anti' technology as such, but as seeking to influence the process of technological change within a wider context of opposed social and ethical values.

It is this perspective on a 'politics of technology' that in my view provides the key to the significance of the 'new production concepts'. They are not conceived solely as 'conceptual organisers' of empirical data concerning what is already happening in industry — although they must, like any useful concept, have a purchase on reality. What they do is engage with the new possibilities of programmable production technologies, and crystallise opposed methodologies for seeking the productivity potential of these technologies. They point to the existence of clear choices — choices which are susceptible to the influence of governments, trade unions and employers, as well as to that of professional managers and engineers. The concepts are tools of intervention.

For purposes of clarity, we labelled these choices as moving in the direction of Computer-Aided Taylorisation (CAT), or in a new direction of Skills-Dependent Innovation (SDI).

The 'new production concepts', with their emphasis in one way or another on the contribution of skilled labour to productivity, all represent, in my submission, instances of the SDI strategy. They seek to enhance and preserve flexibility, but not at the expense of worker interest, responsibility and skill. It is the task of the engineering profession, and its literature, to take these broad concepts and translate them into more concrete criteria of design and principles of management in the specific circumstances of different sectors and workplaces. It is no longer acceptable to describe such criteria and principles as 'objective', without reference to the paradigm within which they make sense. There is great scope for engineers to now *broaden* the range of criteria that may be appealed to in the course of the design process, to break the dominance or monopoly of criteria that derive their rationality from the fading paradigm of mass production, and which have decreasing relevance in the new era of flexibility and skill dependence. In this process, they will bring the worlds of learning and of work closer together — making the firm and its production organisation primarily a 'learning system', with a new capacity to absorb and act on abstract knowledge; while the education and training system will be recognised increasingly as a key factor in the development of competitive advantage in an emergent, post-Fordist industrial system.[52]

The 1990s will provide the real-world laboratory in which these 'competing paradigms' will be tested and refined.

NOTES AND REFERENCES

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2. Charles Babbage, *On the Economy of Machinery and Manufactures*. London, 1832. Reprinted New York, 1963.
3. See D. Hounshell, *From the American System to Mass Production, 1800-1932: The development of manufacturing technology in the United States*, Baltimore, Johns Hopkins Press, 1984.
4. On the rise of corporations, see M. Piore and C. Sabel, *The Second Industrial Divide: Possibilities for Prosperity*, New York, Basic Books, 1984.
5. Taylor's life spans the transition from the 19th to the 20th century. He was born in 1856 into a wealthy Philadelphia family. He was to go to Harvard but dropped out because of poor eyesight, and in 1874 began an apprenticeship as a pattern maker and machinist. In 1878 he took a job at the Midvale Steel Company and quickly rose to be foreman. It was here that he enforced a greater pace of work, but in the end had to leave because of his unpopularity. At the Bethlehem Steel Company he re-organised the handling of pig iron, using the unfortunate Schmidt as his celebrated subject. It was this experience that allowed him to formulate the principles of management, which he began to discuss in papers in the 1890s. By the early 1900s he was the dominant figure in the new 'scientific management' movement, and he and a small group of disciples were busy as consultants to companies through the period to the First World War.

   For a statement of his principles in his own words, see F.W. Taylor, 'The Principles of Scientific Management', in F.W. Taylor, *Scientific Management*, Westport, Conn, Greenwood Press, 1972.

   For a commentary on his place in management history, see D. Wren, *The Evolution of Management Thought*, New York, Wiley, 1979; and R. Reich, *The Next American Frontier*, New York, Times Books, 1983.

6. For an account of the establishment of the Ford assembly line, and the social struggle that surrounded it, see David Gartman, in A. Zimbalist (ed.) *Case Studies in the Labor Process*, New York, Monthly Review Press, 1979.
7. Piore and Sabel, *op. cit.*
8. Much of the literature on this complex of factors has been developed within what is now called the French 'regulation school'. Decisive contributions have been made by M. Aglietta, *A Theory of Capitalist Regulation: The US Experience*, London, Verso, 1970; and by Alain Lipietz, *Mirages and Miracles: The crises of global Fordism*, London, Verso, 1987. Useful reviews of the portmanteau category of Fordism are contained in: Annemieke Roobeck, 'The crises in Fordism and the rise of a new technological paradigm', *Futures*, April 1987; and R. Mahon, 'From Fordism to ? New technology, labour markets and unions', *Economic and Industrial Democracy*, 8, 1, 1987. pp. 5-60.
9. See B. Bluestone and B. Harrison, *The Deindustrialization of America*, New York, Basic Books, 1982.
10. For an unfluential example of this genre, see R. Reich, *The Next American Frontier, op. cit.*
11. See W. Skinner, 'The productivity paradox', *Harvard Business Review*, July-August 1986; pp. 55-59; and R.H. Hayes and S.C. Wheelwright, *Restoring our competitive edge: Competing through manufacturing*, New York, Wiley, 1984.
12. Hayes and Wheelwright, *op.cit.*, pp. 19-20.
13. Charles Sabel, *Work and Politics: The Division of Labor in Industry*, Cambridge, Cambridge University Press, 1982. For similar arguments in the Australian context, see P. Ewer, W. Higgins and A. Stevens, *Unions and the future of Australian Manufacturing*, Sydney, Allen and Unwin, 1987.
14. This is now widely agreed in the literature. For an authoritative statement, see the report of the US Manufacturing Studies Board, *Human Resource Practices for Implementing Advanced Manufacturing Technology*, Washington, DC, National Academy Press, 1986.
15. For a recent statement of this view, see R. Hayes and R. Jaikumar, 'Manufacturing's crisis: new technologies, obsolete organizations', *Harvard Business Review*, September-October 1988, pp. 77-85.
16. R. Jaikumar, 'Post-industrial manufacturing', *Harvard Business Review*, November-December 1986, pp. 69-76.
17. The literature on the 'dual' use to be made of FMS installations — a productive, skill-based approach versus an extension of Taylorism — is growing fast. For excellent examples, see: Fix-Sterz *et al.*, 'Flexible Manufacturing Systems and Cells in the Scope of New Production Systems in Germany', Final report of the German part of the project commissioned by the Commission of the European Communities, *FAST* Occasional Paper No. 135, Brussels, 1987; R. Schultz-Wild and C. Kohler 'Introducing new manufacturing technology: manpower problems and policies', *Human Systems Management* 5, 1985, pp. 231-243; and H. Hirsch-Kreinsen and R. Schultz-Wild, 'Implementation processes of new technologies — managerial objectives and interests', Proceedings of IFAC conference on *Skill-Based Automated Manufacturing*, Karlsruhe, September 1986.
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19. See R. Kaplinsky, *Automation: the technology and society*, London, Longman, 1984.
20. See P. Adler, 'New technologies, new skills', *California Management Review, 39, 1, Fall 1986, pp. 9-28; and O. Bertrand and T. Noyelle, Human Resources and Corporate Strategy: Technological change in banks and insurance companies*, Paris, OECD, Centre for Educational Research and Innovation, 1988.
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University Press, 1989.) For a statement of their views in English, see H. Kern and M. Schumann, 'Limits of the division of labour: new production and employment concepts in West German industry', *Economic and Industrial Democracy*, 8, 1987, pp. 151-170. For an extended review of their text, by Arndt Sorge, see *Economic and Industrial Democracy*, 6, 1985, pp. 501-503. For a recent statement of their position, see H. Kern and M. Schumann, 'New concepts of production in West German plants' in P.J. Katzenstein (ed.) *The Third West German Republic*, Cornell University Press, 1989 (forthcoming). For commentary on the work of Kern and Schumann, see C. Lane, 'Industrial change in Europe: the pursuit of flexible specialisation in Britain and West Germany', *Work, Employment and Society*, 2, 2, June 1988, pp. 141-168 and D. Hoss, 'Technology and work in the two Germanies', in P. Grootings (ed.) *Technology and Work: East-West Comparison*, London, Croom Helm, 1986.

22. Kern and Schumann, 1984; p. 98. Translated and cited in W. Streeck, 1987, 'Industrial relations and industrial change: the restructuring of the world automobile industry in the 1970s and 1980s', *Economic and Industrial Democracy*, 8, 4, November 1984, p. 437-462.
23. M. Piore and C. Sabel, 1984, *op. cit.* For commentary, see C. Lane, 1988, *op. cit.*
24. Piore and Sabel, *op. cit.*, p. 17.
25. Arndt Sorge and Wolfgang Streeck, 'Industrial relations and technical change: the case for an extended perspective', in R. Hyman and W. Streeck (eds), *New Technology and Industrial Relations*, Oxford, Basil Blackwell, 1988.
26. M. Cooley, *Architect or Bee? The human price of technology* (Revised edition), The Hogarth Press, London, 1987, p. 149. Howard Rosenbrock, professor of control engineering at the University of Manchester Institute of Science and Technology, has long been a proponent of 'human-centred' industrial design. His description of a number of years of work is contained in Rosenbrock, 'The combined social and technical design of production systems', paper presented to International Seminar on Advanced Information Technology, Milan, October 1987.
27. Firms mounting such projects in the UK include Rolls Royce and BICC. On BICC's approach to 'human-centred' computer-integrated manufacturing, see A.W.S. Ainger, 'CIM — the human centred approach', *Technology in Action*, January 1988, p. 28-31. A number of demonstration projects are being mounted in BICC Technologies Group factories in the UK. These projects, and others like them, are supported financially by the European Economic Community through its Esprit project 1217 (1199), 'Human-Centred Computer-Integrated Manufacturing'.
28. See for example, the special issue of the journal *Applied Ergonomics* on 'Ergonomics matters in AMT', March 1988. In particular, see Martin Corbett, 'Ergonomics in the development of human-centred AMT', *Applied Ergonomics*, 19, 1, 1988, p. 35-39. See also the Proceedings of the IFAC Workshop, *Skill Based Automated Manufacturing*, P. Brodner (ed.), London, Pergamon Press, 1987. For a specific application within computer-aided design, see A. Majchrzak *et al.*, *Human aspects of CAD*, Philadelphia, Taylor and Francis, 1987.
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31. See the special issue of the German *Industrie magazin*, April 1987.
32. For the 'official' tripartite report on Kalmar, see S. Aguren and others, *Volvo Kalmar Revisited: Ten Years of Experience*, Efficiency and Participation Development Council, SAF/LO/PTK, Stockholm, 1984.
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35. On new systems of management organisation to complement the 'new production concepts', see B. Gustavsen, 'Workplace reform and democratic dialogue', *Economic and Industrial Democracy*, 6, 1985, p. 461-479; and B. Gustavsen and L. Hethy, 'New forms of work organisation: a European overview', *Labour and Society*, 11, 2, May 1986, p. 167-188.
36. On Japan, see for example W.G. Ford, 'Learning from Japan: the concept of skill formation', *Australian Bulletin of Labour*, 12, 2, March 1986, pp. 119-27; and Kazuo Koike (trans. Mary Saso), *Understanding Industrial Relations in Modern Japan*, London, Macmillam 1988; and the chapter on Japan in Hayes and Wheelwright, *op. cit.* It is not denied that Japan has a distinctive culture; but this cannot be allowed to obscure the real innovations in work organization and relentless attention to detail that underlie Japanese prodictivity.
37. On the 'Toyota Production System' see S. Shingo, *Study of Toyota Production System from Industrial Engineering Viewpoint*, Tokyo, Japan Management Association, 1981; K. Suzaki, *The New Manufacturing Challenge: Techniques for continuous improvement*, New York, The Free Press (Macmillan), 1987, and on SMED see S. Shingo, *A Revolution in Manufacturing: The SMED System*, Cambridge (MA), Productivity Press, 1985. On 'Toyotism', see K. Dohse *et al*, "From 'Fordism' to Toyotism? The social organization of the labour process in the Japanese automobile industry, *Politics and Society*, 14, 2, 1985.
38. Shingo is the originator of Single Minute Exchange of Die (SMED) techniques, which have reduced the time for die changes in press lines from 3 or 4 hours to 3 or 4 minutes. Shingo argues that this is the key to flexibility, because rapid die change favours small-lot production; long set-up times have always been an obstacle to flexibility. However, while Shingo explicitly supports a notion of full consultation with skilled operators to learn how to reduce set-up times, he slips into Taylorism when he states (1985, p. 177): 'The ease of tooling changes eliminates the need for skilled workers'; and on p. 126:

    > When the SMED system is imposed, *needed levels of skill are reduced* by means of improved and simplified operations, set-ups are simplified, and set-up times are cut drastically. (emphasis added)

    This is why SMED in the form advocated by Shingo cannot be counted as a 'new production concept'.
39. See Tom Pettigrew, 'Process intent, statistics and participative management in a new model programme — the EA26 experience', Paper delivered to International Workshop on Engineering Design and Manufacturing Management, University of Melbourne, November 1988. For an earlier account of productivity gains achieved at Ford through the 'Process intent' approach to quality control, see T. Pettigrew, 'Process quality control: The new approach to the management of quality in Ford', *SAE (Aust) Journal*, July/August, 1983.
40. For a description of this BHP program, see I.C. Thomas, 'Innovative training: a creative approach', address to conference on 'Education and Industry for Development — Gippsland Region', Victorian Ministry of Education, Melbourne, June, 1988.
41. For a description and analysis of these innovative agreements, see J. Mathews, *Towards an 'Australian Model' of wages — linked regulated structural adjustment*, Stockholm, Swedish Centre for Working Life, January, 1989.
42. On labour market flexibility, of which 'functional flexibility' is a sub-category, see the special issue of *Labour and Society* on 'Labour market flexibility'. In particular, see D. Meulders and L. Wilkin, 'Labour market flexibility: critical introduction to the analysis of a concept', *Labour and Society*, 12, 1, Jan 1987, pp. 2-17. On the 'flexible firm' see J. Atkinson, 'Manpower strategies for flexible organisations', *Personnel Management*, August 1984.
43. There are of course many examples of firms that are attempting to restructure along lines that are very different from those of 'flexible specialisation' and use of 'new production concepts'. An example is provided by the 'flexible firm' approach that is popular at the moment in the UK. A recent Australian study of electronic outwork has demonstrated contrasting approaches, in the case of domestic word processors and that of professional programmers — see B. Probert and J. Wajcman,

'Technological change and the future of work', *The Journal of Industrial Relations*, September 1988, p. 431-448. However, much of the literature perversely seeks to use such examples in an effort to 'refute' Piore and Sabel, by demonstrating how much of industry is still determined to introduce advanced manufacturing technology along Taylorist lines. See for example T. Bramble, 'The flexibility debate: industrial relations and new management practices', *Labour and Industry*, 1, 2, June 1988, pp. 187-209. This literature misses the point that Piore and Sabel are not *describing* an already dominant trend, but pointing to a *tendency* that could become manifest in the 1990s given appropriate conditions. For further discussion of this critical literature, and defence of the 'new production concepts', see R. Badham and J. Mathews, 'The 'new production systems' debate: A reformulation of competing paradigms and strategies', *Labour and Industry,* (forthcoming).

44. For a comprehensive discussion of these issues, see J. Mathews, *Tools of Change: New Technology and the Democratisation of Work*, Sydney, Pluto Press, Australia, 1989.
45. Piore and Sabel, *op. cit.*, p. 5.
46. See C. Perez, 'Structural change and assimilation of new technologies in the economic and social systems', *Futures*, October 1983, pp. 357-375; and C. Perez, 'Microelectronics, long waves and world structural change: new perspectives for developing countries', *World Development*, 13, 3, 1985, pp. 441-463.
47. Perez, 1985, *op. cit.*, p. 441.
48. See R. Boyer, 'New technologies and employment in the 80s', Report No. 8526, CEPREMAP, Paris, 1985; and R. Boyer (ed.) *The Search for Labour Market Flexibility: The European Economies in Transition*, Oxford, The Clarendon Press, 1988.
49. This is the Social Construction of Technology (SCOT) School. Stemming from work in the sociology of science, that seeks to apply the same principles and methods to the development of technology. This 'school' is associated mainly with the names of Law, Latour, Callon, Pinch and Bijker. For a representative sample of their work, see W. Bijker, T. Hughes and T. Pinch, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Cambridge (MA), MIT Press, 1987.
50. On scientific paradigms, see the original exposition by T.S. Kuhn, *The Structure of Scientific Revolutions*, Chicago, University of Chicago Press, 1962, 1970 (second edition). For a critique, see S. Toulmin, *Human Understanding*, Princeton, Princeton University Press, 1972. On the transfer of the notion to technology, see R. Laudan (ed.) *The Nature of Technological Knowledge: Are models of scientific change relevant?*, Dordrecht, Reidel Publishing, 1984.
51. See R. Badham, 'Technologies and public choice: strategies for technological control and the selection of technologies', *Prometheus*, 4, 2, 1986; pp. 288-305. For further elaboration of 'competing paradigms' and politics of technology, see Badham and Mathews, *op. cit.*
52. On education in a 'post-Fordist' era, see J. Mathews, G. Hall and H. Smith, 'Towards flexible skill formation and technological literacy: challenges facing the education system', *Economic and Industrial Democracy*, 9, 4, 1988, pp. 497-522.