"The Nature of Technological Change: Its Implications for Work and Labour Regulation"

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The Nature of Technological Change
Its Implications for Work and Labour Regulation

Anthony E. Smith

This paper applies an analytical framework which, in contrast to most recent research, takes into account the independent influence of the characteristics and capabilities of new technologies. Drawing on evidence from a survey of 435 firms in Atlantic Canada, it concludes that an analysis of the independent influence of technology is a necessary compliment to an examination of the way outcomes of change are a product of choice and negotiation.

The implications of technological change are generally seen to be considerable, indeed many commentators argue that they constitute a new industrial revolution. However, the precise nature of that revolution is the subject of considerable disagreement. Managerialist writers argue that new technology will remove routine jobs and create more skilled opportunities (for example, Kerr et al. 1961; Blauner 1964; Bell 1974). This analysis suggests that, while in earlier phases of industrialization technical developments had tended to reduce skill levels and demean work, more recent technological innovations will have the reverse effect.

Against this view it has been widely argued that new technology degrades work and leads to a reduction in skill levels. This point of view has frequently been associated with theories of the labour process. Hence, for example, Braverman (1974) argued that the degradation of work, in terms of reduction of skill levels, the eradication of any degree of worker control, and the intensification of effort, is crucial to the profitability of large modern enterprises. One of the central means by which this is achieved is through technological innovation.

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Recent developments in the new technology debate suggest that the effects of technological change may be more complex and ambiguous than managerialist and labour process writers have argued. While new technologies eliminate or reduce the range and complexity of tasks requiring manual skills and abilities, they also lead to more complex tasks and new skills requiring mental problem-solving and interpretive skills (Rose and Jones 1985; Smith 1991a). In this author's recently completed case studies, in using new computerized information to control work operations and in deciding on corrective action when problems occurred, new tasks still required tacit knowledge and abilities acquired while using older systems (Smith forthcoming). Thus, although automating some aspects of the control of work operations, new technologies normally require a continued human presence and informed intervention if the control capabilities of the technologies are to be used effectively to complement human information-processing and decision-making skills

The central argument to be presented in this paper therefore starts from the assumption that the process of technological change in an employing organization involves a number of distinct stages. At each stage, issues arise which involve "actors" making choices that are likely to be constrained by a range of "external" factors and also contested and modified over time by other members of the organization. In other words, technological change involves a process of choice and negotiation which, within certain constraints, offers scope for managers, unions and workforces to play a significant role in determining whether change occurs and, if it does, in its implementation and outcomes.

This premise leads to a challenge to deterministic views of technological change as leading necessarily either to deskilling or reskilling of the workforce. However, the paper utilizes the argument advanced by Clark et al. (1988) that an analysis of the independent influence of technology is a necessary *compliment* to an examination of the way outcomes of change are chosen and negotiated. How can this argument be related to the conventional concerns of the regulation of labour such as skill, control, effort and so on? It is suggested here that technological change can be explained less in terms of management strategy to exploit the new technology in order to control workers or to win their consent. Instead, it suggests that employers' primary concern begins with product and market strategies. The capabilities of technology *enable* decisions or choices concerning how the technology will be used and only then do labour questions attract systematic attention.

The specific focus in this paper is on technological change in its most pervasive and significant contemporary guise in Canada - new microelectronic technologies. It utilizes a set of survey data based on 435 unionized employing organizations in Atlantic Canada. The first section of the paper explores technology in the context of long-term developments in the automation of production processes and, in the process, identifies three influential perspectives on technological change: contingency theory, labour process theory and strategic choice. The second section outlines the approach adopted to collect and analyze the survey data and summarizes the significant findings. The conclusions draw together the arguments and findings discussed, and shed light on the implications of technology for work and labour regulation.

NEW TECHNOLOGY AT WORK

New Technology and the Automation of Work

In order to assess the nature of contemporary technological change it is useful to place technology in its historical context. Since the "industrial revolution" three phases of automation can be identified: *primary mechanization,* the use of machinery driven by steam power to replace human physical and manual labour in the transformation of raw materials into products; *secondary mechanization,* the use of machines powered by electricity to accomplish the transfer of materials between machines and to run continuous-flow assembly lines and processes; *tertiary mechanization,* the use of electronics-based computing and information technologies to co-ordinate and control transformation and transfer tasks (see Coombs 1985).

Primary mechanization was predominant until the end of the nineteenth century, while secondary mechanization was most significant during the first half of the twentieth century. Since then, aided by developments in electronics, tertiary mechanization has assumed increasing importance as more aspects of the control of work operations have been automated.

Microprocessor-based applications of computing and information technology can be seen as the latest phase in tertiary or control automation. Microelectronics radically transforms the capabilities of computing and information technologies and extends the range of their applications in both products and in the production process itself. It also makes it possible to innovate in areas of the control of work operations which hitherto could not be "automated". Thus new technology can be regarded as a distinctive stage in the development of process innovations at work. Microelectronics technology, when incorporated into computing and information systems, radically increases their processing power, speed, reliability and flexibility, while decreasing both cost and size. The range of potential applications of computing and information technologies is therefore increased. Indeed, so radical are the implications of microelectronics that it has been regarded as the kind of technology which could stimulate a renewed phase of economic growth in developed economies such as Canada. Governments, therefore, have been particularly keen to promote the adoption of this new technology in the belief that competitiveness and future economic growth are dependent on its widespread use.

One argument for taking this view of competitive advantage is provided by the theory of "long waves" of economic development (see Freeman et al. 1982; Freeman 1986). Put very simply, the idea of "long waves" suggests that, while innovations are constantly occurring, they are transformed into successful innovations only in very specific historical periods. These "waves" of innovative activity are related to long-term economic cycles of boom and slump. Research by Freeman and his colleagues (1982) has shown that economic upturns are stimulated by the widespread diffusion of "new technology systems" in a "bandwaggon" effect. Initially, pioneering firms adopt a new technology in the design of their products and new firms and industries "spin off" from these pioneers to manufacture and sell these new products. They are subsequently bought and adopted as process innovations by "mature" firms and industries which do not have the expertise to develop the new technologies themselves - hence the "bandwaggon effect" as more firms adopt the technology.

According to this theory, the world economy since the mid-1980s has been at the bottom of the slump in the cycle and experiencing a severe economic recession. Many economists and innovation theorists have therefore devoted their attention to identifying the kinds of innovations which may conceivably stimulate the next upturn in the cycle (see Hall 1986; Ray 1986). Naturally, microelectronics, along with other contemporary innovations such as biotechnology, has been viewed as the kind of technology which could be the basis for starting the "bandwaggon" rolling into the next upturn (see Kaplinsky 1982; Freeman 1986; Ray 1986). Many policy-makers and commentators have thus been encouraged to stimulate and support the development and application of microelectronics, in the hope that this will generate the kind of innovation needed to support a renewed phase of sustained economic growth.

Where are the potential applications of these new technologies in production processes? The list appears to be almost endless. The microprocessor can be used in communications, in metal machining, medical diagnosis and so on. It is not the intention here to review the potential applications of new technology. But Table 1 provides examples of the main applications of computing and information technologies in three sectors of employment where some of the most "revolutionary" of the implications of the technology have been predicted – design and manufacturing, offices and administration, and finance.

FIGURE 1

Applications of Computing and Information Technologies

Design and Manufacturing

Computer Aided Design (CAD)
- quantitiative analysis
- interactive computer graphics

Computer Aided Manufacture (CAM)
- computer numerical control
- robotics
- flexible manufacturing systems

Computer Integrated Manufacturing (CIM)
- CAD/CAM
- computer aided production planning
- computer aided measurement and test

Office and Administration

Computing
- on-line processing
- management information systems
- word processors
- intelligent knowledge-based systems

Telecommunications
- electronic mail
- viewdata and on-line data bases
- private automatic branch exchanges
- local area networks

Finance
- automated teller machines
- electronic funds transfer
- integrated circuit cards

Source: McLoughlin and Clark (1988)

Reference was made above to the widely held view in innovation theory that the introduction of new technology in such areas of employment will be driven by commercial and technological imperatives. Where the "impact" of a new technology is found to provide an economic advantage to an adopting firm, then other firms are forced by commercial pressures to adopt the technology in order to be able to compete and survive.

A major problem with such perspectives is the tendency to assume that technology has unavoidable "impacts" on employing organizations. For example, that the decision to adopt a new technology necessarily leads to competitive advantage and economic growth. However, in reality such advantage is determined, not by technical characteristics and capabilities alone, but also by the nature of the process of change within adopting organizations. It is the processes *within* organizations, as well as the "impacts" on them, which are decisive in shaping the outcomes that result from the introduction of new technology. Three influential perspectives which differ from those referred to so far focus on *technological change within the organization and, in particular, at the* workplace: contingency theory, labour process theory, and strategic choice.

Analyzing Technological Change at Work

Contingency theory advances the proposition that there is no "one best way" to organize and manage production. Rather, different approaches are appropriate to particular situations dependent on a range of "contingent" factors such as product markets, labour markets, organization size and technology. The work of Woodward (1970 and 1980) is a classic example of this approach in which "technology" is accorded a primary role as an independent explanatory variable. Woodward's analysis of the relationship between technology (the production system), organization structure (management control systems) and commercial success provided little analytical space for the idea that managerial choice or negotiation with the workforce might be significant influences on the outcomes of change. Rather, the logic of technological progress and commercial requirements meant that managers were required to adapt their organization structure to suit the production system if the organization was to be commercially successful. Similarly the idea that technological change might involve a conflict of interest between management and labour was not seen as significant.

In contrast, labour process theory emphasizes the class-based conflict between capital and labour as the driving force behind technological change and identifies technology as one means by which management seeks to extend its control over the shopfloor. Writers such as Braverman (1974) tended to see management strategy in one-dimensional and mechanistic terms involving the progressive deskilling of job content through the application of scientific management forms of work design and control. Other contributors to the labour process debate, such as Friedman (1977 and 1990), Burawoy (1979), Edwards (1979), Armstrong (1988), Thompson (1990), offered more sophisticated models, stressing the alternative choices that were available to managers in controlling the labour process and emphasizing the way management strategies were shaped by the "contest for control" between capital and labour. However, little significance has been attached by labour process writers to the problems of formulating and implementing management strategies. The approach has tended to assume that strategies to control the labour process flow unproblematically from overall business strategy and that managements act in unison to pursue a single objective.

The third approach, strategic choice, provides an antidote to the weaknesses of both contingency and labour process perspectives. It is based on the idea that the outcomes of technological change are the products of choice and negotiation. This approach suggests that it is the actions of organization actors - managers, unions and workforces - at critical junctures in the process of change which are critical in shaping outcomes and not exclusively technological, commercial or capitalist imperatives.

An important early contribution to this action-based approach was made by Child (1972) who used the concept of "strategic choice" as a means of emphasizing the role of managerial choice, rather than technology, in shaping work and organization. This action-based approach has had considerable influence on recent research concerning the introduction of new computing and information technologies (see, for example, Buchanan and Boddy 1983; Sorge et al. 1983; Wilkinson 1983; Child et al. 1984; Davies 1986; Smith 1991a). Many researchers who have adopted this approach view it as an essential corrective to what is seen as the "technological determinism" of writers such as Woodward and the inadequacies of the labour process approach. In other words, the changes which result from the introduction of new technology are profoundly affected by the decisions made by managers and the way these are contested by unions and workforces within organizations. (For further analysis of this discussion on the historical context of technology see McLoughlin and Clark 1988).

However, does the fact that the outcomes of change are chosen and negotiated mean that technology has no independent influence? While labour process and strategic choice approaches may be justified in the view that technology is not the *primary* explanatory variable determining the content of work and organizational structure, this paper questions whether it is also correct to reject the insight implicit in contingency theory that technology can have an independent influence.

A key argument to be developed in the conclusions of this paper is that an analysis of technology is complimentary to an examination of the way outcomes of change are chosen and negotiated.

So how far are the "technological revolutions" in the world of work implicit in the ideas of the "workerless factory", "paperless office" and "cashless society" actually taking place? The following section analyzes the available survey evidence on the pattern of innovation and current diffusion of new technology in Atlantic Canada. It indicates that although significant changes are occurring, the "technological revolution", if it is to happen, is still at an early stage.

THE PATTERN OF INNOVATION AND DIFFUSION OF NEW TECHNOLOGY

The Survey and Data Analysis

The aim of the survey was both to extend the coverage of the author's case study research in chemicals (automated process-sequence controls), small-batch engineering (CNC machine tools) and the insurance sector of finance (on-line processing), and to test three hypotheses which had developed during the course of these studies. In particular, it was intended to extend the range of industries and sectors beyond those covered by the case studies and to consider variations between the private and public sectors. The analysis in this paper is based on nine samples: chemicals, small-batch engineering, finance, food and drink, electrical engineering, print, civil service and two groups in telecommunications.

In chemicals and small-batch engineering the case study research had focused on production groups and it was evident that their experience was likely to be significantly different from maintenance workers. It was therefore decided to include samples of maintenance workers in these two industries. In addition, to cover large-batch and mass production, samples were also drawn from food and drink, and electrical engineering. Because the responses in these two samples were generally dominated by maintenance workers they have been included as maintenance groups in the analyses. In finance the survey was confined to offices that employed a minimum of seventy-five staff. Otherwise there was a risk that very small units in this sector would be compared with much larger units in other samples. This meant that the population which could be sampled was greatly restricted. Samples were therefore drawn from two sectors: banking and insurance. The small number of responses in these two samples led the researcher to combine them for the purpose of the analysis presented here. Print was selected as an example of a single-industry sector where there has been considerable technological change. It also meant that the number of samples covering predominantly craft workers in a production rather than maintenance role were supplemented.

To assess the impact of new technology required surveying not only the private sector (where the case studies were located) but also the public sector. Samples were drawn from the "mainstream" provincial government departments. Respondents in this sector were chosen to assess how new technology affected different grades of non-manual workers. In addition, clerical workers in telecommunications gave the opportunity to assess similar non-manual work in a different context. Telecommunications also provided a skilled engineering group working at the very heart of new technology.

The first hypothesis explored concerns the extent to which a history of technological change is important. It was suggested above that the reason why microelectronics-based innovations are considered so important is that they may constitute the kind of technology which will support the upswing phase of an economic long wave in a "bandwaggon" effect. The use of microelectronics in the actual design of new technology products such as computers, word processors, robots and machine tools was a necessary prerequisite to their adoption by the mass of other potential users in mature industries that were without the knowledge or skills to develop the technologies in their own production processes. The "bandwaggon" effect in the automation of shopfloor and office work is therefore likely to have begun in the mid-1960s and started in other areas during the 1970s. Significantly, Freeman et al. (1982) suggest that in the past the diffusion of major new technology systems has taken more than thirty years to cover just half of the potential adopters. If their impressionistic model is correct it suggests that the microelectronics "bandwaggon" may only be in the early stages of its journey. For although applications might have been diffused widely in the products and processes of science-based industries such as defence, space and some areas of consumer electronics, they are only now being adopted on a large-scale by the mass of potential users in more mature industries.

The second hypothesis relates to the importance of planned changes that have not as yet been introduced. One of the weaknesses with much existing research is that, while pointing to the diversity and complexity surrounding decision-making over technological change, little is said about the way economic circumstances of the firm, or types of innovations involved, may affect or constrain managerial aims and objectives. Here a number of reasons can be expected to be important.

First, and most obvious, changes may still be in the process of implementation. Some picture of the likely extent of technological change in the future is therefore available. Second, as already mentioned, there may be financial or market constraints on the extent of technological change and it is important to assess how far the recession has imposed checks on the introduction of new technology. Third, through this question some idea can be developed of the degree to which technical problems exist in the process of implementation.

The third hypothesis concerns the extent to which the precise nature of the "core" production process may be relevant to an understanding of the effects of technological change. As already suggested, it is likely that particular types of production process are more amenable to technological change than others. In addition, it is likely that the nature of the core production process will be associated with the particular types of innovation introduced. For example, it is clearly unlikely that technological change will occur in the handling of transactions unless those transactions are an important feature of the work process.

The information was obtained from a mailed questionnaire answered by personnel managers between January and March 1991[1]. Nearly 1,000 questionnaires were sent and 435 had been completed and returned by the time the data had been put on the computer. While the response rate varied between the samples, overall it exceeded 40 per cent. Nearly one-quarter (23%) came from the civil service, with the balance coming from chemicals (16%), engineering (15%), food and drink (13%), telecommunications engineers (10%), print (9%), electrical engineering (6%), finance (4.5%), and telecommunications clerical workers (3.5%). It should be stressed that the survey was of an exploratory nature. The constraints of survey methods, particularly those employing self-administered questionnaires, are well known (see, for example, Jackson 1988). However it seemed that a survey of the kind undertaken could be of considerable use as a means of encouraging a more analytical approach to the study of technological change and complementary to the detail of case studies.

Several statistical techniques were used in the analysis, in particular stepwise regression. The first stage of the analysis permitted a clustering of the different samples into groups that were broadly similar and enabled a development of the various indices used in this paper. These should be seen largely as convenient means of summarizing the data, permitting

1 The survey design included questions which were susceptible to differences in the way the parties perceived them owing to their roles and relationships. Thus management and union respondents were asked questions about the effects of technological change and the extent to which these were the product of negotiation. More factual questions pertinent to the analysis presented in this paper were asked of only management respondents.

an easier discussion of the findings. If the indices are fed into regressions the percentage of variation explained is often considerably lower than if individual variables are used. However, the indices subsume these variables and make the discussion easier. The second stage of the detailed analysis was then undertaken on the basis of the groups of samples, although at the same time keeping note of variations by individual samples; both by reference to the first stage of the analysis and by introducing dummy variables for each of the samples into the analyses. The fine detail of these statistical analyses, however, are only briefly alluded to in the paper.

New Technology at Work: A New Industrial Revolution?

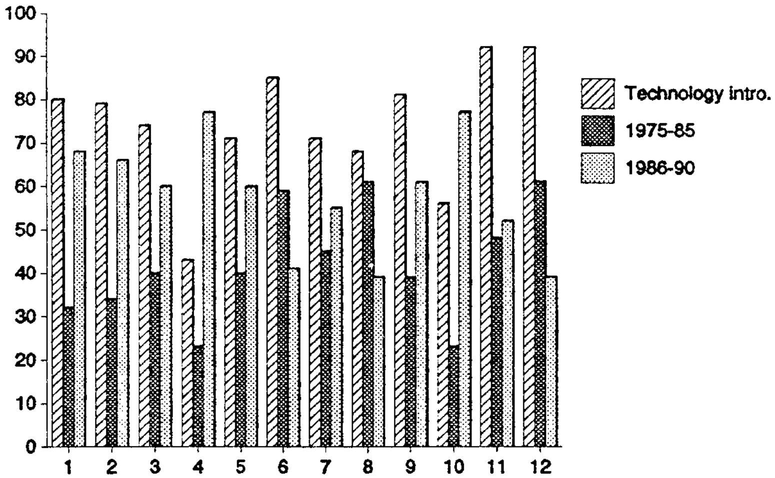
As outlined above, the first hypothesis guiding the research was the extent to which a history of technological change was important. Respondents were asked whether there had been microelectronics applications introduced within their establishment between 1975 and 1985. Table 1 shows that such change had been widespread.

The survey found that microelectronics-based technology had been introduced in the majority of workplaces, in particular telecommunications, food and drink, finance, and print. Although in the civil service and production engineering, microelectronics technology had been introduced in about half of the workplaces, the survey suggests that innovations have, as Freeman et al. (1982) predicted, spread more widely to all sectors to include firms in more mature industries which do not have the skills or knowledge to develop applications of the technology themselves.

The survey also reveals an increasing rate of adoption of microelectronics during the previous five years. While between 1975 and 1985 forty-two per cent of establishments were using microelectronics in their production process, this had risen to fifty-nine per cent by 1990. However, while this suggests a rapid diffusion of the technology, the survey indicates that those samples where significant proportions had little technological change between between 1975 and 1985 were also likely to have had no such change in the previous five years.

Respondents were also asked when the recent phase of technological change began. Table 1 shows that the recent spate of technological change started earliest in telecommunications (in both engineering and clerical) and electrical engineering. That is, the two sectors whose products are so intimately related to the growth of microelectronics technology. Changes had been much more recent in civil service and again in engineering. Thus, those sectors where

Table 1
Use of Microelectronics in Production Processes
(Percentage of all establishments)



Production	Maintenance	Non-manual/public
1. Print	5. Chemicals	9. Finance
2. Chemicals	6. Food & drink	10. Civil service
3. Food & drink	7. Engineering	11. Telecoms (clerical)
4. Engineering	8. Electrical engineering	12. Telecoms (engineers)

technological change started most recently tended also to be those where there had often been no technological change and where there was little history of technological innovation.

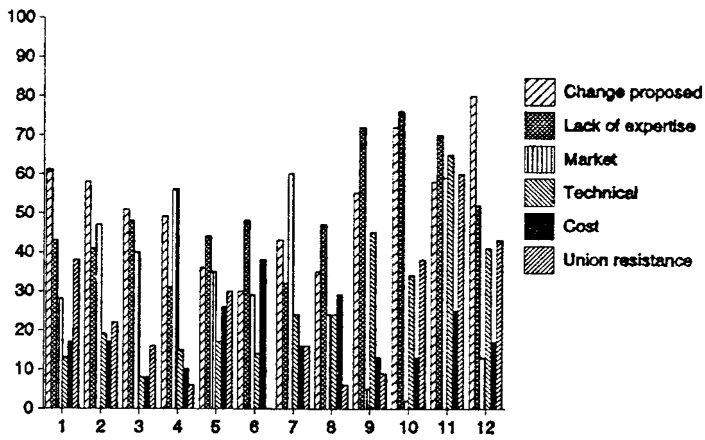
Turning to the second hypothesis, the importance of changes that had yet to go beyond the planning stage, Table 2 shows that there were a significant number of replies which suggested that management had proposed but not introduced changes in plant, machinery or equipment.

In about three-quarters of telecommunications engineering and civil service samples, and about half of finance and production, planned changes had yet to be introduced. While this was often because the changes were in the process of being implemented, it is striking that market factors, along with other cost factors, explain the non-implementation of planned technological change in a substantial number of cases, especially in the private sector. Where market-related factors were less significant, notably among the non-manual and public sector samples, an important reason for non-implementation was technical problems, especially in telecommunications. There is little evidence to support the often articulated but highly simplistic view that trade unions and their members on the shopfloor are a barrier to technological progress and commercial success. The survey suggests that the lack of people with the appropriate skills, and the high costs and lack of finances for development, are far more important barriers to technological innovation than union or shopfloor resistance.

To explore the third hypothesis, the extent to which the nature of the "core" production process may be relevant to an understanding of the effects of technological change, requires a consideration of the activities undertaken by the establishments covered by the survey. To this end the conventional classification of technology identified by Woodward (1980) was employed for the manual samples. That is, respondents were asked whether the main products of their establishments were made as one-offs, small-batches, large-batches, were mass produced or manufactured by means of a continuous process. The general pattern of production processes is shown in Table 3.

One-off and small-batch technologies existed in over half the engineering and printing establishments. There were few major variations between the samples in the extent to which large-batch and mass production techniques were used, but continuous production was concentrated in chemicals and food and drink. However, what is also clear from the table is that in a substantial number of cases more than one of these production methods was employed. In about one in five establishments some combination of the three main types of production -

Table 2
Main Difficulties of Implementing Microelectronics
(Percentage of all establishments)



Production
1. Print
2. Chemicals
3. Food & drink
4. Engineering

Maintenance
5. Chemicals
6. Food & drink
7. Engineering
8. Electrical engineering

Non-manual/public
9. Finance
10. Civil service
11. Telecoms (clerical)
12. Telecoms (engineers)

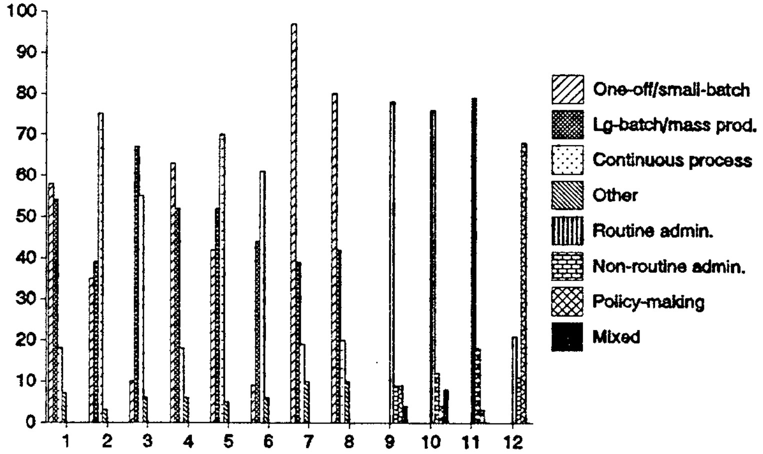
unit and small-batch, large-batch and mass, and continuous process - was employed.

A similar picture is evident among the non-manual groups, where the nature of the "base" technology was obtained by asking respondents whether the bulk of work was routine administration, non-routine administration or oriented to policy-making. About three-quarters in finance, civil service and telecommunications said that the work was primarily routine administration. Nearly a fifth in telecommunications said the work could best be characterized as non-routine administration but only about one in ten of the other respondents described the work in this way. The least common type of work was that oriented towards policy-making; about one in ten respondents in finance said the work was of this nature but there were virtually none in civil service. Finally, a small number, particularly within the civil service, described the work as of a mixed nature.

The final question to be considered here concerns the types of technological change which had been introduced in the previous five years. Manual private sector respondents were asked whether changes in the following areas had occurred: the control of individual machine processes, integrated central control systems, automated handling and storage, and testing and quality control. Table 4 shows that there was little variation in the incidence of changes in individual machine processes, which had occurred in about half the establishments experiencing recent technological change. The introduction of integrated control systems occurred in less than one out of five cases in printing and was only found in less than half of engineering establishments, but was more common in electrical engineering, chemicals and food and drink. Changes in handling and storage were more common in those samples where integrated control systems had been introduced. Finally, changes in quality control and testing had taken place in almost half of all types of engineering establishments.

As in the case of the manual samples, the technological changes that had occurred in the office were characterized in terms of functional areas and activities. Respondents were asked whether changes had occurred in the following areas: information storage and transmission; word processing; transaction clearing and calculations; and management information systems. Changes in information storage were found in at least three-quarters of all samples. In finance and in the telecommunications clerical sample, where much of the work involves dealing with a large number of transactions, changes in methods of handling these transactions were found in four-fifths of cases. In the civil service changes of this kind were only half as common. In

Table 3
Base Technology and Production Systems
(Percentage of all establishments)

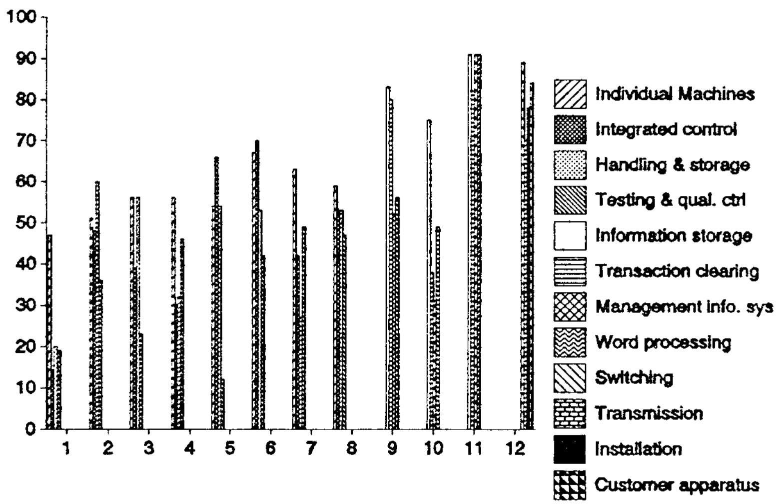


Production
1. Print
2. Chemicals
3. Food & drink
4. Engineering

Maintenance
5. Chemicals
6. Food & drink
7. Engineering
8. Electrical engineering

Non-manual/public
9. Finance
10. Civil service
11. Telecoms (clerical)
12. Telecoms (engineers)

Table 4
Types of Changes in Production Process
(Percentage of establishments where technological change had occurred)



Production
1. Print
2. Chemicals
3. Food & drink
4. Engineering

Maintenance
5. Chemicals
6. Food & drink
7. Engineering
8. Electrical engineering

Non-manual/public
9. Finance
10. Civil service
11. Telecoms (clerical)
12. Telecoms (engineers)

telecommunications changes in management information systems and word processing had occurred in nine out of ten workplaces.

Pursuing the logic of relating technological change to areas of activity, telecommunications engineering respondents were asked whether changes had occurred in the previous five years in switching systems (telephone exchanges), transmission systems (the way in which messages are transferred), installation methods, and the type of equipment used by customers. All four types of change were said to have occurred in at least seven out of ten cases. The most common type of change was in switching systems; the least common was change in the transmission system. With this scale of change it is not surprising that the different types of technological change were even more strongly associated with each other than was the case in the other manual groups and in the office samples. Changes in switching systems were more strongly related to a history of considerable technological change and changes of this kind, along with changes in transmission systems, were associated most strongly with an earlier start to the latest phase of technological change.

In summary, the survey reveals an increasing rate of adoption of microelectronics in production processes during the 1980s. The wide range of potential applications in computing and information technologies was illustrated by assessing usage in public and private services as well as the private manufacturing sector. As outlined above, computing and information technologies are characterized by their ability to capture, store, manipulate and distribute information, and to automate aspects of the control of work operations. Microelectronics radically increases the power, speed, reliability and flexibility but reduces the size and cost of computing and information technologies. The range of potential applications of these technologies is therefore radically increased. It can be regarded as a technology which can support new applications of computing and information systems in sectors of employment and aspects of the production process where the automation of control was previously impossible. In this sense, the microelectronic-based computing and information technologies identified in the survey are distinctive and new.

However, despite the seemingly limitless potential for applying the new technology, the extent of its current pattern and diffusion indicates that its most "revolutionary" implications in the world of work are, at least as far as Atlantic Canada is concerned, still at an early stage. For a detailed examination of the "effects" of technological change was also carried out and this evidence suggests that if technology does indeed have any *a priori* effects, these may be less dramatic and straightforward than assumed by innovation or labour process theorists. There is not the space to analyze the data here. But the broad conclusion from both the case study and survey evidence is that new technologies may generate imperatives which have the following effects on work. First, tasks requiring manual skills are reduced or eliminated and more complex tasks requiring mental problem-solving and interpretive skills are generated. Second, in order that many tasks can be performed effectively tacit skills associated with the performance of work with the former technology are still required. Third, many decisions concerning job content and work organization are made by line managers concerned with implementing and using new technology. Finally, the evidence also suggests that the absence of a detailed consideration of job content and work organization in management strategies can lead to outcomes which allow workers and their unions to re-negotiate the content of their jobs so that the technology operates in a way which compliments rather than replaces their skills. (The case studies are analyzed in Smith forthcoming; the effects of technological change are examined in Smith 1991b; and the extent to which these effects are the product of negotiation is assessed in Smith 1992).

This returns the discussion to the key question raised in the introduction to the paper. To what extent will these new technologies have inevitable and unavoidable implications for work and labour regulation? The concluding section begins by summarizing the principal arguments made and conclusions reached, and then seeks to broaden the discussion by considering some of the implications of technology for work and the regulation of labour.

CONCLUSIONS

This paper began by acknowledging that the outcomes of technological change may be seen as a product of choice and negotiation, and not as a direct reflection of the characteristics and capabilities of technology. However, its central theme has been to identify the technical factors which have to be taken into account in describing and explaining technological change. An analytical framework has been applied which, in contrast to most recent research, takes into account the independent influence of the characteristics and capabilities of the new technology itself (cf. Clark et al. 1988).

The paper has not suggested that organization structures are the product of a need to adapt to the requirements of given technologies for commercial success as implied, for example, in the work of Woodward (1980). Nonetheless, it has been pointed out that the current phase of development is one where the "new" technology is genuinely new. As such "it appears to be malleable and to offer a range of options - centralization versus decentralization; enhancement of skills versus the polarization of skills away from the shopfloor; [and] rigid controls versus delegation of decision-making over production" (Littler 1982: 143).

In considering the nature of technological change in the survey, three hypotheses were explored. The first concerned the extent to which a history of technological change is important. The proportion of workers affected by new technology was greater where there was a history of technological change and where the recent phase of change started earlier. Consequently, the control and co-ordination of work operations here is likely to be more automated than it has in the past. While the data are not of a kind to permit a full evaluation of different arguments it appears that this could not be explained in terms of management strategy, or a conspiracy of gradually exploiting the new technology in order to win worker consent. Instead, the data suggest that employers' primary concern begins with product and market strategies. The capabilities of technology enable decisions concerning how the technology will be used and only then do labour questions attract systematic attention.

The second hypothesis related to the importance of planned changes that had not been introduced. Here the role of market forces and the competitive advantage of new technology affected the scale of technological change. From this perspective the greater effects of technological change over a longer period of time would reflect changes in the market situation. Those who introduced changes at the peak of the business cycle could engage in more widespread technological change. A subsidiary argument is that where new technology was introduced during this peak then companies would have been more competitive and therefore able to introduce further technological change. This finding has important implications. It suggests that those firms who embarked on technological change earlier were able to introduce it more widely because they achieved an advantage in the market place. The exacerbation of market forces in a recession therefore could be expected to check rather than promote the extent to which companies take up technology. Thus, at least as far as the adoption of new technology is concerned, deflationary policies of governments militate against the improved competitiveness of many firms.

The third hypothesis was that particular "core" production systems are more susceptible or amenable to widespread technological change than others. That is, capital intensive and process technologies are inherently more susceptible to technological innovation so that change will start earlier. Along with this there may be a learning curve in relation to new technology. As time passes, management builds up an expertise in the new technology and is thereby able both to use existing equipment more effectively and to see the possibilities of further technological change.

More generally, clearly if the introduction of new technology changes the content of work, this has implications for labour regulation. Kerr et al. (1961), for example, predicted that more advanced technology would be associated with greater flexibility and worker discretion. Similarly, Blauner (1964) suggested that advanced automation would be associated with increased work group autonomy and a decentralization of management decision-making. Consequently, more participative methods of management, based on consent rather than coercion, could be expected. Other writers, such as Woodward (1970 and 1980) predicted that advances in technology would be associated with the development of impersonel and integrated "mechanical control" systems which would reduce the need for the personal supervision of work operations. Many labour process writers (for example, Braverman 1974; Edwards 1979; Thompson 1990) have associated the deskilling of job content with an increasing centralization of management control and the replacement of the need for direct supervision of the labour process by automatic monitoring devices built into the equipment. More recently, the "flexible production" thesis initially advanced by Piore and Sabel (1984) suggests that changing market conditions call for more flexibility in production and that new technologies facilitate this flexibility. This approach has been incorporated in recent transformation theories of industrial relations (see Kochan et al. 1986) to argue that it provides management with the opportunity to grant workers greater job discretion and to pursue more co-operative workplace relations.

Clearly, then, technology has fundamental implications for the regulation of labour. However, one of the difficulties with much existing research is that, while pointing to the diversity and complexity surrounding decision-making over technological change, there is little evidence of the way economic circumstances of the firm, or type of innovations involved, might affect policies concerned with labour regulation (cf. Willman 1986). The survey suggests that the relationship between management's decisions to introduce new technology and policies concerned with labour regulation appear to be more complex than implied in labour process theory. However, while there is little evidence to suggest that issues such as labour costs and labour control are decisive, it is important to recognize that the objectives behind decisions to adopt new technology set parameters within which decisions over industrial relations are likely to be made. Thus, while such issues may not be an explicit component of overall business strategy, policy assumptions on such matters as labour costs can be implicit in management's decision-making.

From this survey it is possible to suggest a categorization of the various factors which may set the parameters for managerial decision-making in this respect. The key factors are whether a firm's competitive position depends on maximizing the performance, maximizing the sales, or minimizing the production costs.

Organizations operating in a relatively young product market are likely to seek to improve competitiveness by applying new technology to maximize the performance of their products, rather than seek to reduce the costs of production. These firms might be expected to introduce policies which aim to develop the skills and expertise of their workforces in order to improve quality and develop new products and services. This description would fit the firms that, according to long wave theory, were the first to adopt microelectronics in new technology production processes and products.

In contrast, firms in maturing product markets are likely to seek to maximize sales by using new technology to improve the efficiency and continuity of production. The implication for labour regulation here is that management policies might be directed at securing greater control over work, while at the same time attempting to secure worker acceptance of continuous technological change.

Finally, firms in mature product markets are likely to seek to maintain their competitive position by using new technology to reduce production costs. Where labour costs are the principal concern, they might be expected to develop policies which aim to improve labour productivity and utilization. Significantly, it is in mature industries concerned with cost minimization that new process innovations based on microelectronics may have their greatest impact. This is supported by the current pattern of innovation which, as seen in Table 1, reveals that microelectronics-based innovations are now diffusing more generally into production processes across industries.

In conclusion, this paper has assessed empirical evidence on the nature of new computing and information technologies. A framework for understanding technological change and its outcomes has been presented, and particular attention has been devoted to the independent influence of technology. It suggests that there are likely to be variations in the implications of decisions to adopt new technology for labour regulation, depending on the nature of the organization's product market, whether the change is a product or process innovation and, if a process innovation, whether this is aimed at improving the quality of output or reducing costs. However, it is not automatic that organizations introducing new technology in any of these circumstances will necessarily develop the "appropriate" business strategy or approach to labour regulation. Rather, processes of "strategic choice" may well be important mediators. Similarly, the author's case studies point to the importance of strategic choices in mediating the link between overall business strategy and labour regulation (Smith forthcoming). In this sense the overall business strategy developed by an organization in response to changes in the commercial and technical environment may at best be seen as a "corporate steering device" (Child 1985) which sets the parameters within which sub-groups of managers, unions and workforces develop and modify approaches to implementing technological change.

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La régulation au travail dans une nouvelle technologie

Il est d'abord souligné dans cet article que le changement technologique implique un processus de décision et de négociation qui, sous certaines contraintes, donne l'occasion aux directions, aux syndicats et aux salariés de jouer un rôle significatif dans la décision d'introduire ou non le changement et, le cas échéant, dans son implantation et ses aboutissements. Ces prémisses tendent à remettre en question l'opinion déterministe selon laquelle le changement technologique conduirait inévitablement à la déqualification ou à la requalification des travailleurs. Néanmoins, doit-on en conclure que le changement technologique, parce qu'ayant fait l'objet de négociations, n'ait pas d'influence directe?

Cet article, à contre-courant de nombreuses recherches récentes, soutient que l'analyse de l'influence directe de la technologie est un complément nécessaire à l'examen des voies suivant lesquelles sont choisies et négociées les issues du changement. Comment alors cet argument peut-il être mis en relation avec les préoccupations plus traditionnelles de la régulation du travail que sont la qualification, le contrôle, l'effort, etc? Il est suggéré que le changement technologique ne puisse guère être expliqué en termes de stratégies managériales d'exploitation de la technologie nouvelle visant à contrôler les travailleurs ou à gagner leur consentement . Nous présumons qu'il le serait davantage si mis en relation avec les préoccupations premières des employeurs, soit les stratégies de développement de produits et de mise en marché. Le potentiel technologique rend possible certains choix concernant ses voies d'application futures et c'est là que les questions abordant la régulation du travail trouvent leur sens.

Puisant ses sources d'une étude de 435 entreprises des provinces atlantiques canadiennes, cet article propose une catégorisation des divers facteurs utiles à l'établissement des paramètres concernant les mécanismes de prise de décisions appliqués à la régulation du travail. Les facteurs-clés de l'analyse relèvent de ce que la position concurrentielle de l'entreprise dépende soit de la maximisation de la performance, soit de la maximisation des ventes ou de la minimisation des coûts de production.

Les entreprises oeuvrant au sein d'un marché du produit relativement jeune sont plus susceptibles de rechercher l'amélioration de leur compétitivité en faisant usage d'une nouvelle technologie dans le but de maximiser leur performance plutôt que de chercher à réduire leurs coûts de production. Ces entreprises introduiront le plus souvent des politiques visant à développer les qualifications et l'expertise de leur main-d'oeuvre et, partant, améliorer la qualité et développer de nouveaux produits et services. Sous un autre angle, les entreprises appartenant à un marché en pleine croissance chercheront davantage à maximiser leur niveau de ventes en utilisant une nouvelle technologie permettant d'améliorer l'efficience et la continuité de la production. Ceci implique, pour la régulation du travail, que les politiques managériales puissent être dirigées pour s'assurer à la fois d'un contrôle accru sur le travail et de l'acceptation, chez les salariés, d'une continuité du changement technologique. Finalement, les entreprises oeuvrant au sein de marchés stables chercheront pour leur part à maintenir leur position concurrentielle en faisant usage d'une nouvelle technologie dans le but de réduire leurs coûts de production. Là où les coûts de la main-d'oeuvre constituent une source de préoccupations majeures, l'on n'hésitera probablement pas à développer des politiques qui tendront à améliorer la productivité du travail et son utilisation.

Toutefois, il ne va pas de soi qu'une organisation introduisant une technologie nouvelle dans l'une ou l'autre de ces circonstances développera nécessairement la stratégie d'affaires ou l'approche appropriée à l'égard de la régulation du travail. Nous croyons davantage en la capacité médiatrice du processus de «choix stratégique». En ce sens, la stratégie globale d'affaires développée par une organisation en réponse aux changements en cours dans les environnements économique et technique pourrait, au mieux, être perçue comme un outil de gestion qui établit les paramètres à l'intérieur desquels les acteurs développent et modifient les approches dans l'implantation du changement technologique.