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New Technologies, Employment and Labour Markets in Developing Countries

Jeffrey James

ABSTRACT

This article is concerned with the impact of new technologies — especially, but not entirely, those that are related to microelectronics — on employment and labour markets in developing countries. Taking the form of a literature survey it looks at those impacts that have already occurred as well as effects that seem likely to occur in the future. Both sets of issues are addressed within an analytical framework that views the impact of technical change as the end result of a process which begins with the generation and proceeds via the diffusion of new technologies. The need for so broad an approach is shown to stem from the multiplicity of ways in which the generation and diffusion of new technologies influence each other and condition the ultimate impact of these technologies on employment and labour markets. Because many such mechanisms have not yet received much attention in the literature, there appears to be substantial scope for further research.

THE GENERATION OF NEW TECHNOLOGIES

The manner in which new technologies are generated exerts a profound influence on the patterns of diffusion that they subsequently exhibit and these patterns in turn bear with no less importance on the ultimate impact of the new technologies (in ways that are described in detail below). It is a fundamental tenet of the induced innovation model, for example, that the direction of technical change in an economy tends to be based on relative scarcity of factors of production (Binswanger and Ruttan, 1978). In the developed countries, where labour tends to be relatively scarce and the wage-rental ratio is correspondingly relatively high, technical change in general can be expected to take the form of labour- rather than capital-saving innovations. Insofar, therefore, as technical

change originates in the developed countries, the nature of the innovations that are forthcoming (in terms of scale, factor-intensity, etc.) is likely to be such that diffusion is concentrated in the developed countries (a line of reasoning which, as shown below, underlies the notion of comparative advantage reversal).

If the generation of new technologies influences patterns of diffusion (and hence impact), it may also be the case that the causality often runs the other way: that is, that the process of diffusion and adoption has a bearing on the type of technology that is generated.

For example, as technology is diffused so its use under a variety of different circumstances leads to the generation of further technological changes as constraints are encountered and improved methods devised. In some cases the problems and puzzles thrown up in the diffusion process will result in the development of new research agendas to be tackled by scientists and technologists. In some cases of biotechnology, such as protein engineering, it may yet turn out that the technological practice will do more for the development of science than the other way round. (Fransman, 1991: 9)

Our understanding of this and other ways in which the new technologies are generated, however, remains somewhat limited. In the context of biotechnology, for example, Fransman points to the very few attempts that have been made to identify future trends, in spite of the immense significance that these are bound to have for diffusion and impact. Part of the difficulty involved in such an exercise is that it is far from clear to what extent new technologies in general, and biotechnologies in particular, are generated in response to economic mechanisms (such as inducements to factor and other scarcities) as opposed to various "technological trajectories and momenta" that are relatively uninfluenced by economic considerations' (Fransman, 1991: 21).

Another part of the difficulty involved in identifying technological trends is the uncertain role of social influences on the generation of the new technologies. In the case of computers, not only are there still questions about what the technology can do, but there are also uncertainties about what society will demand from it in the future. What people think that they want from an emerging technology is inclined to change as the technology itself evolves. Cars, for example, were initially desired essentially for purposes of transport but they also produced a subsequent set of unintended (or 'second-order') effects, such as motorways and pollution.¹ There is

uncertainty too, over the extent to which complementary social innovations will evolve in response to technical change. It is perfectly possible for example that 'a lack of social and institutional (including educational) innovation could culminate in a shortage of the necessary occupations and skills which in turn could retard the rate of technological change' (de Wit, 1991: 45).

What does seem clear though is that the identification of future trends in the new technologies will require detailed study of individual firms in developed countries where, to a very large extent, these technologies are generated. At this level of analysis, future research will need to take account of and to explain the systematic organizational changes that have taken place in recent years in microelectronics, biotechnology and new materials. In particular, there has been a rapid growth in organizational forms (for example, technology co-operation agreements) that are sometimes referred to as 'alliances', since they fall somewhere between Williamson's (1975) categories of markets and hierarchies. Hagedoorn and Schakenraad (1990) suggest, tentatively, that these co-operation agreements in general have less to do with motives of cost reduction than with the long-run strategic behaviour of firms (though in biotechnology the category of cost-motivated agreements appears to have increased recently as research in this area reaches the costly stages of development and commercialization). Hagedoorn and Schakenraad show that the vast majority of all such agreements (over 90 per cent) are concluded between countries from the USA, Japan and Western Europe. Intra-USA agreements comprise the largest share of the total number of agreements in the case of all three new technologies, and especially in biotechnology. In an interesting disaggregated analysis of these regional patterns, the authors find that 'in each of the core technologies the world-leading companies play a very active role' and that 'the globalisation of strategic alliances between the world-leading companies . . . appears most noticeable in information technologies, i.e. the most mature field of these core technologies' (1990: 28).

What, then, are the issues posed by these organizational developments? On the one hand, it could be argued that 'Alliances promote greater information diffusion, thereby increasing efficiency across the economy' (Mody, 1990: 23). On the other hand, one could just as plausibly point to the likelihood of inefficiency that is produced by collusive behaviour on the part of co-operating firms. Furthermore, at the international level, some observers see the trend

towards technological co-operation as a major probable source of future inequalities. According to Chesnais, for example:

Much more research would be required to understand the medium and long-term effects of a situation where the *largest and most advanced firms*, technologically speaking, are exchanging *between themselves* vital, *complementary* technologies. On the basis, however, of available data in the light of the understanding built up by earlier work on *barriers to entry* . . . and *technology gaps* . . . it can safely be stated that such cooperation creates *formidable new entry barriers* at the heart of the industry and with respect to its 'core technology' base . . . ; thus creating new conditions of interfirm and intercountry dependencies, in the form of a whole new web of dependent technological links *vis-à-vis* the industry leaders. This is felt even by advanced small and medium-size OECD countries. It is certain to affect developing countries very strongly in the future. (Chesnais, 1988: 520, emphasis in original)

The appropriate conclusion to be drawn from this quotation is not that all future new technological developments be treated as exogenous to developing and less advanced industrialized countries. On the contrary, it seems to call for an especially high premium on research that is designed to understand and to stimulate the processes by which new technologies are generated in these countries. Let us therefore look at the elements that such a research agenda might contain.

*Research on the Generation and Application of New
Technologies in Developing (and Selected Developed)
Countries*

In its study of blending, the ILO has already made a significant contribution to this area. The numerous cases that have been uncovered by this research span a wide range of countries, sectors and new technologies (Bhalla et al., 1984; Bhalla and James, 1988). These cases suggest that the new technologies can be adapted in various ways to the needs of developing countries and perhaps even to the particular needs of the poorest groups in those countries. However, the distributional impact of blended technologies (including their effects on wages and employment) remains for the most part unclear, due, as Bhalla and James (1988) acknowledge, to a host of severe methodological problems that have still to be surmounted.² Singer's recent study makes the useful suggestion that further

research on these distributional issues be conducted in the context of structural adjustment policies. As he sees it:

Any contribution which this distributional impact could make to poverty reduction, could help to give adjustment a more 'human face' during a difficult and dangerous transitional period in the adjustment process; it could also help the adjustment process to the extent that the traditional element in the new blends can be based on combining new equipment needed with the use of existing equipment, thus economising capital and foreign exchange. (Singer, 1990: 45)

Important though it undoubtedly would be, such research does not address the wider range of issues that arise in connection with the generation of new technologies. The point is that blending is by no means the only form taken by this process, nor, of course, is it the only area in which governments involve themselves. It is these extended patterns of innovation that should accompany blending in future research in this area.

For one thing, although the vast majority of technical co-operation agreements were (as noted earlier) concluded between firms from within the 'Triad' of the USA, Japan and Western Europe, a minority ranging from 5.4 per cent in biotechnology to 9.7 per cent in new materials did not conform to this pattern (Hagedoorn and Schakenraad, 1990). According to the authors who compiled these estimates, a large proportion of the agreements outside the 'Triad' include collaborative projects with South-East Asian newly-industrializing countries. To this extent at least, therefore, developing countries 'are being integrated into the international technology developments' (Reddy, 1991: 20). A related recent tendency is for multinationals engaged in the generation of the new technologies to locate research and development (R and D) facilities in certain developing countries (Reddy, 1991: 20). Since the mid-1980s, for example, a number of prominent multinationals engaged in microelectronics and biotechnology have been locating R and D centres in India. (The group includes IBM and Digital from the USA and Pharmacia from Sweden.) In Mexico a number of research projects in biotechnology are sponsored by multinationals 'with a view to commercializing them not only in Mexico, but also in other countries' (Reddy, 1991: 25). In the semiconductor industry, circuit-design centres have been established by a number of US firms in Hong Kong, Singapore and Taiwan (Henderson, 1989). In these and other similar cases, research is needed to assess whether and how the R and D activities in new technologies actually

spill over as benefits in the form of enhanced local technological capabilities.

There is also the whole question of protecting domestic technological capabilities, a policy that has been pursued by a number of countries (such as India, Cuba, Brazil and the Republic of Korea) in relation to both microelectronics and biotechnology. While some aspects of these experiences have already been examined (see for example Fleury, 1988), there remains a need for a more systematic study of the differential degrees of success that have been achieved and identification of the factors that best seem to discriminate between cases of success and those of failure. Attempts to compare country experiences in a particular application of new technology, along the immensely detailed lines charted in a recent article by Evans and Tigre (1989), seem especially promising. They compare the respective efforts made by Brazil and Korea to promote indigenous innovation in the 'super-mini' computer industry and they show that in order to understand the different outcomes, one needs an analysis of 'differences in state structures and policies, forms of industrial organization, and relations between local and international industry' (Evans and Tigre, 1989: 1752). One important difference, for example, seems to be that the Korean state exhibits 'a degree of cohesiveness that far exceeds Brazil's current capabilities, and its consequent ability to focus a variety of organizations and instruments on particular policy goals has given its informatics policy a scope that Brazil's cannot match' (1989: 1761).

Within *given* countries, there is an especially pressing need to come to grips with the role of externalities of various kinds in the generation and application of new technologies. For it is on the nature and magnitudes of these non-market mediated mechanisms that decisions about whether and how to enter the new technology 'systems', ought in part to rest. That externalities may often be closely related to technology transfer and technological change is not of course a proposition that is peculiar to the new technologies. On the contrary, using the Republic of Korea as a basis for their analysis, Pack and Westphal make the general claim that 'pecuniary externalities related to investments in technology — in acquiring technological capability and in undertaking technological effort — are ubiquitous in industrialization' (Pack and Westphal, 1986: 111). They contrast this conclusion with that which follows from the neoclassical point of view, namely, that in the absence of monopoly

(or monopsony) power, 'the only potentially significant sources of market failure are internal economies and externalities associated with human capital formation. But there can be no market failure unless it is associated with human capital formation' (Pack and Westphal, 1986: 107). The comparative neglect of externalities that are related to technological issues follows, according to these authors, from the predominance of this neoclassical view of the industrialization process.

The need to redress this state of affairs seems all the more cogent in the context of the new technologies, for a number of reasons. The first concerns the high and increasing degree of convergence between and within these technologies themselves. Not only are there growing convergences between microelectronics and communications technologies, for example, but also between these and biotechnology (as in the field of bio-informatics, in areas such as automated bioprocess control and automatic DNA synthesizers).³ Although some of the externalities to which these interactions give rise may be 'internalized' in various ways, it is more than likely that others will not be.

Rapid change in the new technologies is another factor that, via the operation of dynamic externalities, impinges on the way that decisions about 'points of entry' need to be made. For example:

A static comparison of the choice of technology to make mechanical watches or electronic watches in a labour-abundant economy may show that the technology for mechanical watches has the highest benefit-cost ratio among existing technologies. But because electronic watches probably will soon make mechanical watches and their technology obsolete, the better choice may be electronic watches, despite their lower apparent benefit-cost ratio. This choice is more apposite if little of the experience acquired by producing mechanical watches can be transferred to the production of electronic watches. Moreover, producing electronic watches from the start may enable the building of skills that will later be useful for more complicated electronic watches and other products that have electronic components . . . choosing the right technology involves simultaneously optimising the static and dynamic elements of the choice. (Dahlman et al., 1985: 13)

Dynamic externalities also figure prominently in some influential recent explanations of 'best-practice' applications of the new technologies in microelectronics. Best (1990), for example, has suggested that the success of the Japanese and 'Third Italy'⁴ experiences turns importantly on the numerous ways — social as well as organizational — in which externalities between and within

firms were able to be 'internalized'.⁵ One of the questions that is raised by this view is whether similar organizational and institutional forms can be introduced elsewhere (a question pursued below).

Still other challenging issues are raised by the notion that positive externalities may be created by a particular sequence of policies. Concentration on a particular 'leading' sector, for example, may confer various advantages and opportunities for other sectors. Mody (1989), for instance, attributes part of the success achieved by Taiwan and Korea in electronics production to the attention that these countries paid to policy sequencing in general, and to the role of consumer electronics in particular, as a leading sector. Similarly, in recent years Japanese market promoting policies have concentrated on high-technology sectors, such as semiconductors, computers and telecommunications. The Japanese view these industries, like steel and shipbuilding in the past, as providing infrastructure on which the future competitive success of a variety of sectors depends. A policy of promoting R and D, investment and growth in these new 'infrastructural' activities is accordingly viewed as generating beneficial effects throughout the economy (Tyson, 1988).

Most recently, Stewart and Ghani (1991) have systematically examined the whole question of dynamic externalities and part of their analysis and case-study material is related to technical change in general, and to new microelectronics technology in particular. They contend that 'Dynamic externalities are likely to be more pervasive in industries subject to considerable technical change. . . . Industries with broadly stable or slowly changing technologies will not experience the same level of externalities.' They suggest furthermore that 'The extent of technical change in an industry and consequently the potential dynamic externalities may differ according to the stage of development of the country — i.e. more industrialized countries may have reached the stable plateau (or slowly changing technology) while in other countries, the industry is experiencing rapid technical change as it catches up to the frontier country' (Stewart and Ghani, 1991: 575).

For all the importance that these numerous studies appear to ascribe to the concept, only Stewart and Ghani give serious attention to how different types of externalities might actually be *measured*. Yet, it bears emphasizing that 'If policy interventions are to be justified on the basis of externalities, it is necessary to have some idea of potential orders of magnitude involved, in principle,

before decisions are made' (Stewart and Ghani, 1991: 585). Although this is a notoriously difficult task, Stewart and Ghani's work provides an important point of departure for future research on the topic. They attempt, for example, to measure the dynamic externalities that arise from the transfer of technology between firms by the movement of workers; from the technology that is transferred by networking of different kinds; and from innovation that is induced by interactions between firms. It is clear, though, that a great deal more empirical work could be done on these mechanisms by studies that are designed specifically for this purpose.

The Direction of Innovation in New Technologies

An essential complement of research that is designed to throw light on the process by which new technologies are (or ought to be) generated, must be the direction of the technical changes. For it is the features of these changes — the particular crops they affect, the factor-use patterns they imply and the characteristics of the products they manufacture — that largely determine who will gain from them, who will lose and who will remain unaffected. It is not at all obvious that the capability of generating new technologies in developing countries will result in technical change with features that are considered to be socially desirable. Indeed, the scattered evidence that is available tends if anything to suggest precisely the opposite tendency.

In the case of India's protected microcomputer industry, for example, so much protection was apparently granted to the local manufacturer, that there was no incentive to produce goods that were in any sense appropriate to local needs (Grieco, 1984). In biotechnology, a set of ILO case studies demonstrates all too clearly that existing capabilities in the Third World are generally not being applied in directions that the alleviation of mass poverty would dictate (in spite of the vast potential for this purpose that many of the new techniques are shown to afford). With respect to micro-propagation techniques, for example, the 'scientific capacity that developing countries possess is being channelled mostly to cover non-food crops and to meet the needs of the commercial and large-farm sector. This is clear from the developments in the Philippines, Mexico and India' (Ahmed, 1992: 208).

Examples such as these point to the need for future research to focus on the formulation of *countervailing influences* over the direction of technical change in new technologies. One line of research, for instance, would need to examine how the many public sector institutions concerned with the new techniques actually function, in organizational as well as political economy terms, and how these behavioural patterns impinge on the observed directions of technical change. This would entail, among other things, an attempt to understand the role of and interactions between various interest groups in public institutions; for such a purpose a number of specific techniques such as linkage analysis, pay-off matrices and functional analysis are available (Biggs, 1990). Detailed case-study evidence along these lines would make the formulation of effective policy reforms more likely, in much the same way that case studies of the sort conducted by Evans and Tigre (1989, described earlier) would contribute to the design of policy towards the generation of new technologies.⁶

Another, related, research line could profitably examine the role that 'niche' markets might play in a redirected pattern of technical change. In the biotechnology context, for example, Fransman has argued that:

... production for speciality markets ... based on Third World resources and problems, may prove particularly important and may facilitate an additional amount of 'South-South' trade. Examples might include the genetic engineering of plants adapted to tropical climates or vaccines, for use in humans or animals, against tropical diseases. These areas may not appear to be profitable to large multinational corporations. (Fransman, 1991: 61)

In microelectronics, as well, similar ideas need to be explored. An early study of Argentina suggested that small-scale firms are likely to have a comparative advantage in a number of specific areas, such as industrial process control, medical electronics equipment and applications software (Maxwell, 1983). The advantage that small firms seemed to possess in these areas was thought to reside in their ability to meet 'idiosyncratic' local needs, the satisfaction of which tended to be neglected by large-scale companies. In another interesting example, Taiwanese CNC manufacturers have been able to make adaptations to their products that were especially well suited both to the markets of other developing countries and to particular market niches in some developed countries (Fransman, 1986).

THE DIFFUSION OF NEW TECHNOLOGIES

The previous section emphasized that the manner in which new technologies are generated exerts a profound influence on the subsequent phase of adoption and diffusion. This section is concerned with the manner in which the latter phase itself bears on the ultimate impact of the new technologies on employment and income distribution.

The Mechanisms of Influence

There are at least four mechanisms through which the diffusion of new technologies exerts an influence on the ultimate impact of these technologies:

(a) The *speed* with which the process of adoption and diffusion occurs. This is important in the first place, because it determines whether impacts of the new technologies are realized gradually or abruptly (Mowery, 1988) which, in turn, influences the ability of governments to take countervailing policy action (in the event that the impact is regarded as being negative).⁷ The speed of diffusion is also important because it governs the time period over which the adjustment of production processes and structures to changes in factor input proportions occurs. 'In the short run factor substitutability is very limited for technical, organizational and to some extent for legal reasons. . . . Thus, the nature and extent of substitutability is heavily dependent on the time period under consideration' (Kugler et al., 1990: 191).

(b) The *extent* of diffusion of the new technologies is obviously important but not in any simple additive sense. We have already seen that pervasive externalities may often make it unhelpful to analyse the behaviour of individual firms and institutions in isolation from one another. In addition, and relatedly, the extent of diffusion and adoption of the new technologies determines whether partial or general equilibrium methods should be used in assessing the employment and other effects of these technologies (James, 1985). In particular, partial methods of analysis tend to be relevant in conditions where diffusion is confined to a limited sector or region of the economy. The reason is that in such circumstances one can reasonably ignore the various effects of the given sector or region on others in an economy and the subsequent effects of these, in turn, on the original sector or region. On the other hand, in

circumstances where the new technologies are spread widely across different sectors or regions, it becomes necessary to use general-equilibrium methods of analysis (which are able to capture the various feedback effects that are occasioned by the diffusion of these technologies).

(c) The *form* in which the new technologies are diffused refers to whether these innovations take the form of products, processes or organizational changes or some combination thereof. These distinctions bear on the impact of the new technologies in several different ways. The returns that can be expected from the 'hardware' form of the new microelectronics technologies appear, as noted previously, to depend relatively heavily on whether they are accompanied by organizational changes of various kinds. In addition, the distinction between product and process change has been prominent in much of the discussion on the employment effects of microelectronics innovations, not least because of the view that the 'impact of product innovation on employment is more likely to be favourable than is the impact on employment of process innovation' (Katsoulacos, 1986: 150).

(d) The need to study *patterns* of adoption and diffusion is based on the recognition that the impact of adoption by a particular unit (firm, household or region) cannot be disassociated from the decisions of other units. In fact, the decision by one unit to adopt a new technology is often likely to have consequences for *non-adopters*, whether these be individuals, households, firms or countries (James, 1991). These effects (which in principle of course can be positive or negative) are imparted in a variety of different ways. For example, the adoption of a new technology by a firm or region may lead to diminished markets for non-adopting firms. Or, in a pattern that is familiar from the agricultural sector, non-adopters suffer from the price reductions that are caused by the increased output of adopting units. In still another pattern that is worth mentioning, where adopters of new technologies are drawn from relatively high-income groups, the distribution of income may become more unequal even if adoption itself imparts no deleterious effects on non-adopting groups. (In the United States, for example, a recent study commissioned by the Brookings Institution suggests that workers who use computers earn between 10 and 15 per cent more than comparable workers who do not; and since the latter tend to be drawn from relatively low-income groups, the effect is a widening inequality of the distribution of earnings.)⁸

The Speed of Diffusion of the New Technologies

Across a range of microelectronics applications, ILO and other studies find that the pace of diffusion has been slower than was originally anticipated. In the automobile sector, for example, the ILO volume of country case studies concludes that 'The rate of diffusion of microelectronic machinery has been much slower than anticipated and its systematic application . . . is rare' (Watanabe, 1987: 181). An ILO volume on textiles comes to a similar conclusion, namely that 'Even though some extremely high rates of growth of sales of automation technologies have been recorded, the rate of penetration across industries has been much slower than many observers had predicted earlier' (Hoffman and Rush, 1988: 15). In the finance sector, still another ILO study draws attention to the various social and organizational 'moderators' that 'have served to ensure that, where applied, [new] technology has been assimilated only gradually into working methods so that its job-saving potential is realised only over a period of time' (Rajan, 1990: 8).

Findings such as these are not, however, particularly surprising when they are confronted with the received theory on the diffusion of innovations or with the history of previous waves of technical change. Indeed, these literatures together strongly suggest that 'adoption of an innovation by all of the members of a given industry, firm, or sector can take decades for a number of reasons' (Mowery, 1988: 481). Much depends on the conditions under which replacement investments are made and in particular on the idea that it may often be rational for firms to continue to use old technology in spite of the existence of new best-practice methods. For example, under conditions of high capacity utilization and an expected temporary demand expansion, 'it may be wise not to scrap less profitable machinery and equipment in favour of the most profitable equipment, but to just be content with the gross profit margin on old equipment and not incur additional fixed costs associated with replacing old machinery and equipment' (Meijers and van Zon, 1991: 5).⁹

The speed at which the new technologies are adopted and diffused also depends, of course, on factors such as profitability, which also bear on the extent of adoption; the discussion of the latter that now follows is thus relevant to the former as well.

The Extent of Diffusion of the New Technologies

From the supply side, new technologies raise profitability when they reduce costs of production at a particular factor-price ratio. There are a number of different ways in which this may occur. Whereas many of the new microelectronics technologies appear, for example, to save primarily on labour requirements per unit of output, certain organizational innovations that have been inspired by the Japanese automobile industry (such as the 'Just-in-Time' system), save on the amount of capital tied up as work-in-progress (Edquist, 1992).

In addition, new technologies may increase profitability from the demand side; indeed one of the most striking findings to emerge from numerous firm-level studies is that considerations of product quality and flexibility of production are uniformly amongst the most important factors in decisions to adopt the new technologies. The studies also reveal that these considerations (product quality and flexibility of production) are closely related to exports not only through product quality requirements for competition in markets for final goods, but also through the standards for inputs that are often induced thereby (James, 1991; James and Bhalla, 1991).

In some ways, the primacy of products and markets in decisions to adopt technology is a familiar story. After all, the need to produce to international standards is one of the most commonly cited reasons for adopting capital-intensive techniques, especially in the case of relatively large firms in developing countries (Stewart, 1987). Yet, in other ways, what recent research findings seem to reflect are new elements of international markets, elements of what Best refers to as 'The New Competition'. As he sees it, a new competitive paradigm is emerging, which 'is not about maximizing profits for a given material, product, process, and organizational method, but about seeking a competitive advantage by continuously upgrading product, process and organization' (Best, 1990: 144). In this competitive process, time plays a crucial role in two different ways:

The first is about process time, or the time that materials take to be processed within a plant. . . . The second is an extension of Schumpeterian competition: economies of time in the implementation of new product designs. Firms can succeed by being the first to identify and respond to an emerging market, a segmenting market, or a change in consumer requirements in a previously stable market. Responding to changing market demands means being able to supply consumers with a newly designed market; it will involve refinements in production methods

and technologies. In each of these cases *success depends not upon being the lowest cost (or highest throughput) producer, but upon the minimization of product development and product changeover times*. The neoclassical presumption, that eventually the firm with the lowest cost production methods will dominate in the marketplace, does not account for the increased relevance of the capacity to compete on the basis of product, process and response times. (Best 1990: 14, emphasis added)

Exemplified as it is in the Japanese (automobile) and Italian (Third Italy) cases, the 'New Competition' clearly poses fundamental challenges for those firms and countries that wish in the future to enter into it. What is much less clear though (as will be emphasized below), is the extent to which this form of competition undermines the competitive advantages of those firms, in developing and developed countries, that cater primarily to markets in which demand changes relatively slowly and in which price rather than product differentiation is dominant (that is, markets that form part of the 'Old Competition').

This question, and indeed most of the attention that is paid in the literature to the determinants of diffusion of the new technologies, is concerned with the users of new technologies. Considerations of how *owners* of proprietary knowledge in new technologies choose to exploit these assets, on the other hand, tend to be relatively neglected. Yet, especially in the light of the tendency towards increasing technological co-operation among the main players in the USA, Europe and Japan, it is increasingly to the supply side that one needs to look for an understanding of the extent (and pattern) of diffusion of the new technologies in both developed and developing countries.

More specifically, there is a need for future research to address the following issues:

(a) The different types and degrees of appropriability that may be associated with various forms of the new technologies. In some cases, for example, in spite of the formal appropriability that is afforded to owners of patents, it may be possible for competitors to 'patent around' an innovation in various ways (Fransman, 1991). Reverse engineering is another way in which the appropriability of new knowledge may be limited. More generally, it is useful to distinguish between 'relatively tight appropriability regimes where a firm, through one means or another, is able to limit the leakage of its knowledge base or its use by competitors. The converse applies in the case of loose, or weak appropriability regimes' (Fransman, 1991: 26).

(b) How owners of a *given* degree of proprietary knowledge choose to exploit it. There is some evidence, for example, that multinational firms – as the principal owners of proprietary knowledge in microelectronics and biotechnology innovations – choose on the basis of whether they are oriented towards domestic markets or towards exports. There is also evidence regarding the factors that govern whether foreign investment rather than licensing is the preferred mode of exploiting proprietary knowledge in microelectronics (James, 1991). Fransman (1991) provides a valuable discussion, based on case studies, of the problems confronting the two main groups of privately-owned biotechnology firms, namely, the large established firms (such as Monsanto) and the newly-established firms (such as Celltech and Genentech). However, much remains to be done in this important area, not least applying the newly-emerging theoretical ideas from the industrial organization literature (such as Teece, 1988) to understanding and comparing observed patterns of firm behaviour.

(c) The implications of (a) and (b), above, for firms and other institutions in developing and developed countries that seek to gain access to the new technologies.

There is a small but important literature on the scope that licensing proprietary microelectronics technology from *small-scale* firms (in developed countries) might afford to certain developing countries (Tigre, 1983; Evans and Tigre, 1989).

A final consideration for research on the supply side of diffusion of the new technologies is the fact that even when these technologies *are* internationally available, developing countries may still continue to depend on the behaviour of suppliers. Edquist and Jacobsson, for example, regard this as an important constraint on the diffusion of flexible automation techniques in developing countries. The problem, as they describe it, is that in industries which are highly dependent on the use of service or application engineering, suppliers may simply not be concerned to send the relevant personnel in these areas to 'marginal' markets (Edquist and Jacobsson, 1988).

The Form of Diffusion of New Technologies

On the whole, diffusion studies have focused on embodied versions of new technologies, rather than on 'organizational' innovations of

various kinds (although this generalization is more true of some studies than others). As a result, we know relatively little about the latter and even less about its relationship with the former: whether, in particular, there *is* any relationship; whether, if so, the causality runs in one direction rather than another; and whether the direction of any relationship takes the form of complementarity rather than of substitutability.

In answering these questions, one has to confront the fact that in practice a variety of different patterns can be discerned. It is instructive to consider the following five categories in particular.

(a) Where new technology in embodied form is adopted without organizational innovation: a number of firms in Fleury's (1988) sample of firms in the Brazilian engineering industry seem to fall into this category. Indeed, of the automobile industry in that same country, it has been said that 'microelectronics-based automation is not superseding Fordist work organisation but reinforcing it' (Schmitz and Carvalho, 1987: 22).

(b) Where organizational innovation is adopted without embodied versions of the new technologies. Interestingly, some such examples were also discovered in Fleury's study; they have been observed in some small light engineering firms in Argentina as well (Roldan, 1991). The latter apparently evolved as a response to the economic crisis of the 1980s and they raise the important question of whether organizational changes (along Japanese or other lines) may in fact offer an alternative to new microelectronics technologies for developing countries that are heavily constrained by foreign exchange and investible resources.

(c) Where adoption of embodied technologies has been a precursor of organizational innovation. This is what seems to have occurred in General Motors, which underwent 'a major reorganization . . . as a result of the widespread application of IT in its products and processes' (Freeman, 1987: 58). Similarly, a recent study of the diffusion of computer-aided technology in German industry (Ewers et al., 1990) identified a number of firms in which the use of this technology had prompted a variety of organizational changes (although there were also firms in the sample in which this induced effect did not occur).

(d) Where organizational changes precede the adoption of embodied technologies. The Japanese automobile industry is perhaps the clearest example in this category; contrary to what is often thought to be the case, the well-known organizational changes

in this industry pre-dated by many years the introduction of microelectronics technology (Womack et al., 1990).

(e) Where organizational and technological changes are simultaneously adopted. Drawing again on the automobile industry, one could point here to the manner in which British and American subsidiaries of Japanese producers are established on the joint basis of organizational and microelectronics innovations.¹⁰

The Pattern of Diffusion of New Technologies

Quite a lot of information is now available regarding patterns of diffusion within particular countries, at the sectoral level as well as the level of firms of different types. Most of this literature is on developed countries but in recent years a number of studies have emerged on developing countries as well (see James and Bhalla, 1991).

On the whole these studies find a pattern of distribution among firms that one might, on theoretical grounds, tend to expect: that is, a pattern in which the larger firms, on account of their greater technical and financial resources, know-how and information, adopt new technologies earlier than relatively small-scale enterprises (though there are a number of exceptions to this general finding, in particular the various industrial agglomerations that form part of the 'Third Italy').

Rather less research has been addressed to identifying patterns of diffusion between rather than within countries. Even in this area, however, a number of important contributions have already been made. Mowery (1988) and Flamm (1988), for example, both compare rates of diffusion of microelectronics-based innovations in the USA with those of other developed countries such as Japan. Other studies, by Hoffman and Rush (1988) and Edquist and Jacobsson (1988), compare patterns of diffusion in developing countries with comparable data for certain developed countries. In both cases, microelectronics-based innovations (such as CAD and NCMTs) have been adopted far more extensively in the latter than in the former group of countries. It is difficult, however, to draw any firm conclusions from these findings. On the one hand, they appear only partly to reflect factor price differences that make new technologies more profitable in developed than in developing countries; other factors, such as information imperfections and government policies

have also played a role in the differential rates of diffusion (Edquist and Jacobsson, 1988). On the other hand, it is not at all clear from either of the two studies whether, and to what extent, the observed patterns of diffusion are likely to be translated into a loss of export markets for the developing countries concerned (a question that is discussed below in the context of comparative advantage reversal).

To sum up, then, research on diffusion has tended to focus on demand rather than supply-side issues and on embodied rather than organizational innovations. Future work on the conditions of supply of new technologies (with perhaps a particular focus on biotechnology) needs to consider the extent of appropriability of these technologies, the manner in which owners of the proprietary knowledge thus appropriated choose to exploit it and the implications of both these issues for developing countries.¹¹ Future research on the diffusion of organizational innovations ought in part to consider how such patterns are related to those of embodied technical changes: from even a cursory classification of cases, it seems that these interrelationships are anything but simple. This line of research should also pay close attention to the *outcomes* of decisions to adopt organizational changes. It cannot be assumed that these changes always, or even generally, turn out in the way that is expected of them. On the contrary, one needs to take into account not only instances where organizational structures are discontinued after adoption, but also the many implementational problems that drive a wedge between what is *expected* (in terms, for example, of productivity gains) and what is actually *realized* from these innovations (Pennings and Buitendam, 1987). In the developing country context, the problems may be compounded still further: in particular, 'Inadequate command over technology that is not embodied in machines does not bode well for the establishment of plants in these newer industries, because the technical problems inherent in nontraditional and rapidly changing know-how are added to organizational deficiencies' (Pack, 1987: 147).¹²

THE IMPACT OF NEW TECHNOLOGIES ON EMPLOYMENT AND LABOUR MARKETS

From a policy point of view it is desirable to identify the impact of new technologies on output (efficiency), employment and income distribution. If these effects all work in the same direction, be it

positive or negative, the case for or against new technologies is easily made. If, on the other hand, some effects are positive and others negative, the decision involves trade-offs and the weighting of different policy objectives (Stewart, 1989).

Most empirical work has tended to focus on the employment effect largely in the context of a partial equilibrium framework. It has shown that even at the level of the firm and even with a labour-saving bias, new microelectronics technologies need not necessarily lead to unemployment. In fact, several of the studies (e.g. Dominguez-Villalobos, 1988; Onn, 1989) suggest that for some firms an increased demand for exports may have more than offset the labour-saving effect, thus resulting in an increase in the demand for labour. Underlying cases such as these is the important distinction between product and process innovations and the likelihood that the former will in general have a more favourable impact on employment than the latter.¹³ There are several aspects to this. One is that increased product differentiation, or closer manufacturing tolerances in the production of certain goods, permit output (often in the form of exports) to rise beyond the level that could be achieved only on the basis of price reductions of *existing* products (which, in many cases, are likely to be subject to 'satiety' constraints of one form or another). Watanabe (1987) refers, for example, to the 'work-amplifying' effects of new technologies in the automobile industry that are caused by product differentiation and innovation. In other sectors, such as finance and services, the demand-side effects on employment follow partly from the ability of some of the new technologies to overcome geographical and time constraints on consumption (Soete, 1987).

In a general equilibrium context, numerous effects need to be considered that fall outside the purview of a partial equilibrium framework. For example, labour-saving technical change may tend to reduce the costs of capital goods which, in turn, may lower investment costs in other sectors. Moreover, because they often reduce costs of production or introduce new products, labour-saving innovations will lead to an increase in aggregate demand. So far, however, almost all research on these and other general equilibrium effects of new technologies on employment, have been conducted in relation to the developed countries. In addition to the studies conducted in the 1980s that are reviewed in Kaplinsky (1987), recent years have seen a number of other major research projects in this area.¹⁴

One such project involves macro-modelling of the German economy in order to predict the future employment consequences of an 'accelerated introduction of technical change' (Blazejczak, 1990: 345), while another research programme has as its major goal the provision of a detailed macro and sectoral analysis of the employment effects of new information technology in the context of the extended European Common Market (van Zon, 1991). With one or two exceptions (Lee and Tank, 1989; Labys, 1990), what is strikingly absent from research at this level of analysis is modelling of the economy-wide effects of biotechnology or microelectronics innovations in *developing* countries. This in spite of the fact that in some such countries diffusion of the new technologies has progressed to the stage where general equilibrium effects are likely to be substantial and the fact that these effects are unlikely to be easily extrapolated from the developed country results (not least because, unlike industrialized nations, most Third World countries will need to import much of the new microelectronics equipment).

The efficiency aspects of the new technologies have also suffered comparative neglect: there have been very few recent attempts to assess the efficiency of the new as against conventional technologies. As a result, it is difficult to gauge the extent to which efficiency or output gains might compensate for any reductions in employment or increases in inequality that may be associated with the new technologies. Empirical studies designed to address this question ought perhaps to pay particular attention to two issues. The first concerns the recent rapid fall in the cost of certain microelectronics-based innovations, such as CAD, which may make adoption efficient even at developing country factor price ratios. The second issue is related to economies of scale and in particular to the notion that the new technologies allow efficient production at lower scales of output than was possible with more conventional technologies. Though this claim is very frequently made, there is virtually no empirical evidence to support it.¹⁵

Although there is much literature that bears on the income distribution impact of the new technologies, it is nevertheless difficult to reach any firm conclusions on the issue. There are several reasons for this. One of them is the diversity of ways in which various new technologies impinge on labour markets and earnings. Some effects, for example, work through the demand side of these markets, as when there are changes in demand for skilled and unskilled labour. Other effects, in contrast, work through the

supply side of labour markets to the extent that new technologies alter 'labor/leisure, marketwork/home-work choices made within the family' (Blackburn and Bloom, 1988: 231).¹⁶ Some effects are imparted through factor-saving biases that are familiar from standard economic theory, while others refer to mechanisms that are not part of any such theory and are less well understood.

An important case in point is what in recent years has been variously described as 'the new competition' or 'flexible production'. Storper and Scott, for example, have described a number of ways in which these emerging modes of production bear on labour flexibility, a concept which 'refers in general to a logic of tailoring labour inputs in production to shifting levels and qualities of output' (Storper and Scott, 1990: 575). As they see it, labour flexibility in its various forms (which range from high-technology manufacturing and revitalized design-intensive craft industries to financial and producer services) tends to have a polarizing influence on wages (and other dimensions of work, such as job security). For example, the flexible labour market is depicted as being composed of 'groups with different levels and types of security and vulnerability' which in turn 'leads to *income* variation resulting from differential access to working time over and above that based on skill differences, and the corresponding hourly *wage* differentials' (Storper and Scott, 1990: 589). In addition, 'The uncertainties endemic in flexible labour markets diminish the incentive, both for firms and workers, to invest in on-the-job training and the acquisition of new skills. Ultimately, this may . . . launch some workers on a downward wage spiral with its attendant polarisation of wages' (Storper and Scott 1990: 590).

The difficulty of assessing the income distribution effect of the new technologies is compounded by the fact that these and other mechanisms of influence are often strongly conditioned by the context in which they occur. Consider the debate on skills that has received so much attention in the literature on microelectronics-based innovation. Some contributors to the debate have argued that the effect will mainly be a 'de-skilling' of the labour force, as the new technologies destroy craft skills and fragment jobs into routine and alienating tasks that can be performed by unskilled operators. Against this, others have argued that automation will enable precisely these monotonous tasks to be performed by machinery, thus enabling the labour force to shift to more complex operations that require higher levels of education and training. (This is sometimes

referred to as the 'professionalization hypothesis'.) This debate is addressed mostly in case studies on the service and finance sectors (e.g. Rajan, 1990) and in a very considerable number of other studies as well (e.g. Marstrand, 1984; Schettkat and Wagner, 1990; Spenner, 1988; Francis, 1986; Daniel, 1987).¹⁷ The general conclusion of this literature seems to be that neither of the polar cases operates over a wide range of situations. Rather than being any simple (direct or inverse) function of the new technologies, skill requirements seem to depend to a large extent on the social context in which the new technologies are applied. Indeed, in some cases, depending on differences in markets, management and the way production is organized, the very same technology may appear to raise or lower qualification requirements. (To this difficulty in attributing observed outcomes to technical change as opposed to other factors, should also be added the methodological problems of comparing studies that use different concepts and measures of skills.)¹⁸

Much the same ambiguity, which results from context specificity, seems to apply to the flexible labour issue as well. For while there may indeed be cases where flexibility has the polarizing influences that were described above, in other settings the outcome may be somewhat different. The very recent ILO Technical Report on the footwear and leather industries, for example, cites the cases of Cyprus and the Third Italy, where flexibility of production 'was, in general not disadvantageous to labour' (ILO, 1992: 145). Furthermore, other recently reported case studies on the United Kingdom give rise to doubts as to whether 'a new, coherent system of "flexible" production has been established. Though we find plenty of cases of new policies that might be described as increasing "flexibility", they are of such variety and occur in such ad hoc ways that more general claims appear exaggerated' (Bagguley et al, 1990: 213).

The Changing International Division of Labour and the Global Location of Jobs

The new technologies are all giving rise to fundamental changes in the world economy, not only with respect to patterns of international trade but also with regard to the distribution of direct foreign investment. One important consequence of these changes will be an alteration in the distribution of jobs in the world economy. Although this issue has been widely addressed in the literature

(mainly in relation to microelectronics), it is still far from well understood; partly as a result, there is little basis on which to predict the patterns of change, and especially those that bear on the distribution of jobs between the rich and poor countries.

An early hypothesis, specifically related to microelectronics, was based on the notion of 'comparative advantage reversal', that is, a loss to developing countries of export markets and direct foreign investment that was thought to follow from the introduction of new technologies predominantly, or entirely, in the developed countries. Both theory and subsequent experience, however, suggest that this hypothesis is in many ways an oversimplification of a much more complex reality.

First, though there is some evidence (as noted above) that rates of diffusion of several of the new technologies have been more rapid in the developed than in the developing countries, one cannot properly conclude from these observations that the latter have suffered from a corresponding reversal in their comparative advantage.¹⁹ One reason for this is the (generally neglected) role of product characteristics in international trade. This demand-side factor is likely to have a crucial bearing on the outcome of the relationship between adopters and non-adopters of the new technologies, be these countries (as here) or firms within countries (as in the sections above). It is quite possible, for example, that as the characteristics of products traded internationally move in a 'high-income' direction due to adoption of the new technologies, certain developing countries are able to maintain, or even in some cases to increase, their competitive advantage in simpler and less expensive product varieties, an advantage that may find expression in increased trade between developing countries. More generally, what needs to be recognized is that there are in fact a large number of export markets, each with its own demands for quality, and that changes in one market do not necessarily impinge on others. It seems clear enough, for example, that clothing exports from Prato in the Third Italy do not compete to any significant extent with exports to highly price-sensitive ends of the clothing market; but intermediate cases are less clear and require research of a highly disaggregative kind.

A similar neglect of demand-side considerations is apparent in the debate over the alleged relocation of foreign investment from developing to developed countries. In particular, an unwarranted emphasis on the supply side, or cost determinants of direct foreign investment, has led to the neglect of the role of growing markets in

some developing countries as a countervailing influence against the predicted relocation away from those countries. A fairly recent study of the electronics industry in Brazil, for example, concludes that foreign computer firms were 'much more interested in Brazil's *market* than in the price of its labour' (Hewitt, 1988: 170, emphasis in original).

Even on the supply side, it is clear that the early 'relocation back to the North' hypothesis is seriously deficient. In the semiconductor industry, for example, in spite of a strong tendency to automation of the production process, a number of factors seem to militate against substantial relocation of foreign investment to the industrialized countries.

First, indirect labor . . . engineers and technicians . . . has become a significant input into automated assembly and such labor, like direct operator labor, is much less expensive in offshore locations. Secondly, inspection of assembled devices is still a labor intensive process and the low cost of labor in developing countries like Malaysia makes it economical to perform more thorough inspection than could be justified in high wage locations. Thirdly, automated assembly requires considerable expertise which no longer can be found in sufficient quantity in the industrialized countries. Developing country assembly locations have acquired a comparative advantage in such operations which a mere shift in cost structures cannot alter. (O'Connor, 1989: 19)

In other markets, such as textiles, garments and footwear, it is true that the 'New Competition' — with its emphasis on speed of production and product flexibility — confers an advantage on locations in or close to final markets. Even in these markets, however, the emerging locational trends seem to be more complex than the comparative advantage reversals hypothesis would suggest. In fact, what firms in these markets often appear to seek is a *combination* of low wage costs and short turnaround times. It is largely for this reason that Jamaica is becoming an increasingly important location for garment production directed to the US market (Mody and Wheeler, 1990). Similarly, in footwear, 'Men's dress shoes, and men's and women's casual shoes, are increasingly made in the industrialized nations, using uppers cut and sewn in lower cost countries' (ILO, 1992: 117).

For these and other reasons, one has to conclude that the emerging locational pattern of production in relation to microelectronics-based innovations is a complex one. It is equally apparent that if future patterns are to be predicted with any degree of accuracy, this

complexity has to be analysed and incorporated into models designed for the purpose. To date, only one attempt has been made along these lines for a selected group of developed and developing countries. On the basis of very detailed micro-economic data, Mody and Wheeler constructed a complex simulation model that is capable of predicting (in three different sectors) how comparative advantage is likely to alter in the coming five to ten years (Mody and Wheeler, 1990). Their model is capable of predicting not only which countries are likely to be affected by emerging microelectronics technologies, but also the costs and benefits of locating particular parts of the production process (such as the assembly stage) in off-shore locations, and the costs and benefits of locating production in the proximity of final markets. For this last calculation, Mody and Wheeler have attempted to actually quantify the time element associated with different methods and locations of production. In the garment industry, for example, they find that alternative technologies 'have very different throughput rates, and transit times between countries differ substantially. Inventory-related interest costs must also be considered, since buffer stocks accumulate at each stage of the production process' (Mody and Wheeler, 1990: 45-6).

However, no studies at all exist to aid policy-makers who are (one would think, frequently) confronted with the related question of whether not adopting the new technologies will result, via a loss of export markets, in fewer jobs than would follow from the *adoption* of those same techniques. The most one finds are descriptions of the variables that are likely to affect the outcome and some informed guesses about the direction that this will take in particular cases. In his discussion of the US experience, for example, Mowery has this to say on the topic:

If one believes that adoption will have a massive labor-displacing impact, policies to increase the rate of diffusion of these technologies are of little interest. If, on the other hand, one believes that the aggregate job destruction effects of widespread adoption of these technologies are likely to be minor, and that the increasingly open character of the U.S. economy makes rapid adoption necessary to prevent even greater job losses, policies to support more rapid diffusion are appropriate. This survey takes the second view of the consequences of adopting computer-based manufacturing technologies. (Mowery, 1988: 497-8)

To the openness of an economy one ought, following the earlier discussion, to add the *nature* of the markets in which an economy

competes (for it is this which will determine the extent to which products associated with the new technologies actually compete with existing products). Whatever the chosen variables are, it is evident that the policy dilemma posed by Mowery involves a counterfactual and it has therefore to be addressed in the context of a simulation analysis of some kind. In the present context, this form of analysis could make an important contribution to the policy debate, as it does so clearly in the Mody and Wheeler study; it ought therefore to be accorded a high priority in future research.

There is a need too, to model and project the trends in international trade and the location of production that are beginning to emerge from research on biotechnology and new materials technologies (e.g. Ruivenkamp, 1989; Labys, 1990). One recent study, for example, sought to estimate the impact of synthetic bST on milk production in the USA and to assess the effects that this would have on other dairy exporters (Chadee and Guthrie, 1991). Using a simulation model of the dairy market in the United States, the study finds that over the period between 1991 and 1995, surpluses for export could amount to between 5 and 22 billion lbs. Assuming that the European Community also adopts bST, the resulting surpluses could lead to a significant decline in world prices of dairy products. Whether or not these particular estimates turn out to be accurate, the methodology used is illustrative of how further work might be conducted in this area.²⁰

NOTES

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1. This example, as well as a more general discussion, is to be found in *The Economist*, 23 November 1991.

2. Some of these problems are discussed below.

3. These examples are taken from Fransman (1991).

4. 'Third Italy' refers to the vast network of very small firms located in the villages and small cities of central and northeast Italy.

5. Best (1990: 11) contends that the 'New Competition' is distinguishable from its predecessor in four ways: 'organization of the firm, types of coordination across phases in the production chain, organization of the sector and patterns of industrial policy'.

6. There is a more general point here; although science and technology-related institutions in the Third World appear to have performed rather poorly on the whole,

there are very few studies that attempt to explain this outcome.

7. On the 'disruptive nature' of technical change see Bosworth (1983).

8. Cited in the *International Herald Tribune*, 15–16 February 1992.

9. See also the discussion in Stoneman (1983).

10. These are sometimes referred to as 'transplants', to reflect the attempts to replicate as far as possible the plants in the home country.

11. Caves (1982) has an excellent review of some of the theoretical issues that are involved in these questions.

12. Pack (1987) shows that even with more conventional technologies there are often striking gaps between best-practice and actual productivity levels attained in developing countries. He also shows that organizational factors are often critical in explaining these differences.

13. As the available biotechnology studies indicate, even with no product innovations, the employment effect may be positive in partial equilibrium terms (Ahmed, 1992).

14. For a recent review of this literature see de Wit (1991).

15. The claim is argued in most detail by Kaplinsky (1990). Against this, Alcorta (1992) has recently suggested that the impact at firm level may be 'scaling-up' rather than 'de-scaling'.

16. Bosworth (1983) argues rightly that the impact of technological change on the supply of labour has been relatively neglected. According to Blackburn and Bloom (1988: 231), the impact 'arises from the effect that technological change has on the nature of commodities consumed by the household and on the nature of production within the household. The major source of such changes in recent years involves the expanding supply of commodities that reduce the time required to maintain a household of a given quality (such as child care or new products in food preparation, house cleaning and home entertainment).'

17. Most recently, de Wit (1991) reviews a number of these and other studies on the issue.

18. This last problem is emphasized especially by Spenner (1988).

19. A good survey of the issue is contained in Castells and Tyson (1988).

20. It is worth emphasizing that many of the strategic materials likely to be substituted are supplied by developing countries. Future research dealing with the way that this process is shifting market shares away from developing countries, will need to confront the fact that, 'At the moment, existing classifications of industrial production and trade do not allow the analysis of AM's [advanced materials] international exchanges' (Malaman, 1990: 153).

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