Kaplinsky, Raphael. "Chapter 6: AT In the Industrially Advanced Countries." *The Economies of Small: Appropriate Technology in a Changing World,* Intermediate Technology, London, 1990, pp. 135–168.

CHAPTER 6

The economics of small: AT in the industrially advanced countries

As pointed out in Chapter 1, the problem of technological appropriateness cannot be limited to DCs or to the concern with rural poverty. It has a much wider relevance and the AT movement continues to flourish in the industrially advanced countries. Moreover, as was argued in Chapter 1, the three branches of the AT movement — environmental, social and economic — had common origins, representing a response to the degradation of a particular mode of global economic growth. Indeed, two of these branches — those concerned with social and environmental appropriateness — first found their expression in the IACs. So notwithstanding the primary focus of this book on the problems of alternative technology in the developing countries it is also illuminating to consider briefly its role in the First World.

While it is possible to focus on all three of the dimensions of appropriateness in the IACs, only the economic is discussed in this book, and this is considered only in relation to the question of optimum scale. As was seen in Chapter 1, since the mid-nineteenth century there has been a preoccupation with bigness in the IACs. The logic of this is now increasingly being examined, and the 'economics of small' are becoming more apparent. This focus on small-scale is merely an examplar of the more general need to consider the nature of technology in the IACs.

It is important to note that the social appropriateness of technology is also being questioned in the IACs, for example in relation to the optimal pattern of work-organization. The organization of work in the mass-production era emerged over a period of many decades. It involved the specialization of tasks and hence the polarization of skills. Supervisory tiers of management were introduced and information flowed downwards, from the top of the managerial hierarchy to the detailed worker at the bottom. This form of work-organization was alienating and increasingly came to be associated with conflict on the shop-floor, absenteeism, poor quality and often expensive products. This has been referred to as the 'degradation of work'.[1]

But market conditions have begun to change, and the basis of competition in global markets is altering from the mass-production era's emphasis on price to one in which product innovation and performance are paramount. In a context in which price was the major determinant of competitiveness, labour could be seen as a cost which had to be minimized. But when flexiblity, innovation and quality become important, labour must be seen as a resource. Consequently the most efficient firms are moving from this inherited pattern of work-organization to one which emphasizes multi-tasking and multi-skilling, and gives substantial autonomy back to the detailed worker. Whilst in itself this does not necessarily optimize the quality of working life, it does represent an improvement over the patterns prevailing in the mass-production era. It also provides plenty of scope for attempts to enhance further the quality of working life.

These issues of social appropriateness will not be considered here.[2] But it is important to note their emergence as a major policy concern in the IACs, since it illustrates that the introduction of socially appropriate technologies need not necessarily be associated with a loss of competitiveness. To the contrary, there are reasons to suppose that many socially inappropriate technologies are outdated and can only be operated at the risk of reduced competitiveness. These developments provide an important potential boost to the AT movement in the IACs, although there is not much evidence that AT activists have yet grasped their significance.

Similarly, the neglect of environmental appropriateness in this book does not arise because it is irrelevant to the problems of IACs. Indeed, concern with these issues is currently probably higher on the political agenda than at any previous stage of history. The greenhouse effect — resulting from the simultaneous production of carbon dioxide (most of which results from the use of carbon-based fuels in the IACs) and destruction of oxygen-producing forests (most of which lie in the DCs) — is rapidly coming to be recognized as a major environmental hazard whose solution necessarily lies in co-ordinated international action. Acid rain is harming animal and plant life. It arises not only from the inappropriate use of energy-intensive technologies, but also from the particular technologies which are utilized in the production of energy.[3] The reduction of the ozone layer probably results from the utilization of noxious chemicals (CFCs) in refrigerators and aerosols and this is likely to have untold environmental and health consequences. And inorganic chemicals continue to build up in the environment, resulting both from energy-intensive agricultural production and from industrial effluents.

There has been progress in some areas and more environmentally benign technologies have been introduced. For example, the utilization of energy seems to have grown more efficient since the 1973 oil-price shock — the ratio of oil use in the OECD countries (in tonnes per $1,000 of GDP per capita) fell from 0.29 in 1973 to 0.18 in 1988. Yet even these levels of fuel-use appear to be too high for a sustainable environment. Moreover they partly result from energy-intensive and polluting industries moving to the DCs — both Korea and Taiwan increased their oil-consumption by more than 20 per cent in 1988 alone.[4]

Consequently there are grounds for concern regarding both the environmental and social appropriateness of the technologies utilized in the IACs. But s nce this book is primarily concerned with the problems of DCs, we have only limited scope for considering the problems of the IACs. This will

be done by concentrating on economic appropriateness and, in particular, on the issue of the optimal scale of operations.

The emerging concern with diseconomies of scale

Schumacher was by no means the first to be concerned with the problems of large-scale organization and production. Yet his 1973 book *Small is Beautiful: A Study of Economics as if People Mattered* played a major role in concentrating attention on this issue. His personal background had been as a senior economist in Britain's state-owned National Coal Board which for many years had pursued scale economies in organization and production. Schumacher was first sensitized to the problems of scale by the NCB's attitude to the problems of pneumoconiosis, a lethal disease of the lungs associated with coal-mining.[5] Instead of recognizing the self-evident health consequences of coal-mining, the NCB chose to defend itself rigorously and to fight (and subsequently win) the legal argument on technicalities. In saving itself relatively small sums of compensation (£2–3m), Schumacher believed that the NCB had ceased to concern itself with people. More importantly, he believed that such uncaring attitudes were not exceptional but were an inevitable consequence of the organization's scale.

Thus modern economies, believed Schumacher, are on a 'collision course with nature'. At the root of the problem, he argued, was the widespread assumption of unlimited resources and the unrestricted carrying power of nature. This had led modern society to act as if material production could be equated with satisfaction and happiness. As a result, technologies that were seen as maximizing output were considered optimal. For this collision path to be avoided, an alternative set of technologies is required:

> In industry, we can interest ourselves in the evolution of small-scale technology, relatively non-violent technology, and technology with a human face, so that people have a chance to enjoy themselves in new forms of partnership between management and men. (Schumacher (1973) pp. 17–18)

In this plea Schumacher encapsulated all three branches of the modern AT movement — the environmental, the social and the economic. For him the key to understanding the problems of modern technology and the design of alternative paths lay with the problem of scale. This affected the environment since

> Small-scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature. (Ibid. p. 31)

It also affected economic performance, as

> production from local resources for local needs is the most rational way of economic life, while dependence on imports from afar and the consequent

> need to produce for export to unknown and distant peoples is highly uneconomic and justifiable only in exceptional cases and on a small scale. (Ibid. pp. 53–4)

Finally, the social costs of large-scale organization are clear to all (except, that is, to economists):

> Most of the sociologists and psychologists insistently warn us of . . . [large-scale organization's] inherent dangers — dangers to the integrity of the individual when he feels as nothing more than a small cog in a vast machine and when the human relationships of his daily working life become increasingly dehumanized, and dangerous also to efficiency and productivity, stemming from ever-growing Parkinsonian bureaucracies. (Ibid. p. 225)

Schumacher provides a ringing plea for a new attitude to life and a new form of technological progress, one which would emphasize smallness rather than 'giantism'.

> I have no doubt that it is possible to give a new direction to technological development, a direction that shall lead it back to the real needs of man, and that also means *to the actual size of man*. Man is small, therefore, small is beautiful. To go for giantism is to go for self-destruction. (Ibid. p. 148)

This plea of Schumacher, to the extent that it has been heard in the world outside of AT, is largely a moral one. Human beings ought to encourage a greater use of small-scale technology and organization because it will improve the quality of life and because large-scale production is environmentally unsustainable. If this means a loss of material output, then it is is a sacrifice worth bearing. But this normative reading of Schumacher too often ignores a further strand of his argument, that is that the ever-growing commitment to largeness was economically inefficient. However, he believed that the costs of scale were largely realized in the form of external diseconomies. By that he meant that the real costs were not borne by the direct producers but by society at large.

It is in this consideration of the economic costs of scale that important developments are beginning to emerge. Increasingly, scale is not seen as a necessary concomitant of economic growth, but rather is recognized as a factor — perhaps the factor — which reduces its rate. Moreover, no longer are the costs of scale only reflected in external diseconomies, they are now increasingly being experienced by the direct producers themselves. A touchstone of the importance of these new trends is to be found in their discussion in the business literature. This is relevant because this body of opinion is not concerned with the ethical or social characteristics of scale, nor with external diseconomies, but merely with its impact on the rate of economic growth. Here it is increasingly common to find a disillusion with mass production and large-scale organization. The perspective of the flexible

specialization school (briefly considered in Chapter 1) is gaining increasing importance. Piore and Sabel consider the 'limits of the model of industrial development that is founded on mass production' and the 'production of standardized commodities' (1984, p. 4) and review the 'recent historiography of technology [which] clearly documents the vision of automatic machine production as a structuring principle of Anglo-American, particularly American, technological developments' (p. 45). The root of contemporary economic problems is thus traced to the coming to dominance of large-scale, automated mass production in the mid-nineteenth century which, especially in the US and the UK, forced out small-scale craft-based production. Piore and Sabel argue that those countries such as Italy and Japan which have maintained this small-scale flexibly-oriented craft sector are the ones which have come to dominate and it is the mass-production economies which are now in relative decline.

Another indicator of the growing awareness of the economic costs of large-scale technology can be found in a best-selling book by Tom Peters.[6] In the early 1980s he had co-authored an account of 12 of the most efficient US corporations,[7] only to find that within a short space of time, many of these exemplars were facing severe economic difficulties. Facing up to this, Peters offers a critique of 'the American perchant for giantism' and the associated obsession with quantity, rather than quality:

> Big, not best, has always been the American calling card. In fact, I bet you can't drive more than seventy-five miles in any direction, from anywhere in the United States, without running into a 'biggest in the world' of some sort. Wide-open spaces and an apparently limitless frontier set it all in motion . . .
>
> This all-American system — long production runs, mass operations — paid off with victories in World Wars I and II, and cemented subsequent US economic dominance. But we won World War II with *more* tanks and planes, not, in general *better* ones. (Peters, 1987, pp. 15–16)

By contrast the Europeans (except the British) maintained their tradition of product excellence. More pertinently, Peters pointed out that the Japanese challenge has been underwritten by its continual commitment to the virtues of smallness. He notes

> the unique Japanese passion for smallness, in a world where the advantages of smallness seem to be fast eclipsing the once generally perceived value of giantism. (Ibid. p. 18)

Interestingly, Peters quotes at length from a Korean scholar (author of a book entitled *Smaller is Better: Japan's Mastery of the Miniature*) to show the prevalence and historic depth of smallness in Japanese culture.[8]

The brunt of Peters's argument is that giantism is neither efficient nor innovative. He cites evidence from a variety of industries that large-scale plants have often failed to realize the supposed productivity gains arising from scale economies in production. Similarly, there is little evidence that large multi-plant firms display superior performance to their single-plant rivals. The new drive towards flexible production also appears to be facilitated by smallness of plant size. In relation to innovation he also casts doubt on the advantages of scale and quotes the distinguished authors of *The Bigness Complex* who argue that 'the smallest firms produced about four times as many innovations per R&D dollar as the middle-sized firm and 24 times as many as the largest firms' (Peters, pp. 23–4). In fact only 34 per cent of all major innovations in the US come from firms employing more than 10,000 people, despite their much larger share of overall US production.

Yet although there is obviously evidence of a move towards smaller scale in production and organization, in many sectors there is a simultaneous tendency towards a growth in scale. It is important therefore to try and understand some of the reasons why there has been a sudden interest in smallness as opposed to giantism. This will help in defining a series of relevant policy issues: on balance, will the post-1980s trend towards smallness outweigh the inherited momentum of bigness: are there sectoral biases in the economics of small; and are there different dimensions of the economies of small? In the discussion which follows attention will be given to a variety of technological and organizational trends which affect economies of scale. Most of these are only emerging as important trends in the early 1990s and have not yet had a wide impact on scale. The discussion which follows, therefore, is only suggestive of the sort of issues which are affecting the optimality of scale, mostly (but not exclusively) reversing the historic trend towards greater concentration.

The nature and determinants of scale economies

Some relevant concepts

The discussion of economies of scale has a long tradition in economic theory, beginning in the nineteenth century when fixed and indirect costs were first emerging as important elements in production. Given that the underlying factors determining scale economies have inevitably changed over this long time period, it is not surprising that scale has become a somewhat ambiguous concept. Pratten's general definition in a well-known study of the early 1970s is pitched at the most general level and begs the complexity of scale: 'Very crudely economies of scale are reductions in average costs attributable to increases in scale. They can be defined, most readily, in relation to plants'.[9] Similarly, in the 1930s Viner distinguished between the long- and short-run cost curves. The latter consisted of the envelope of the former: 'The long-run cost curve shows the lowest possible cost of producing at any scale of output after all possible adaptation to that scale has taken place', whereas '[t]he short-run cost curve traces out the relationship between the average costs of production and the extent to which plants are utilized'.[10] This, too, provides

only a general description of scale economies and is of limited insight into an exploration of their cause.

These classic views on economies of scale are restrictive because they both refer to only one dimension of scale, that of plant-size. But this is only one type of scale economy. In the analysis which follows, three different dimensions of scale are discussed, informed by Silberston's illuminating distinction between time periods, products and units.[11] The reason why the classical theories of scale economies conflated these three dimensions is that hitherto they have tended to increase in concert — an increase in one was generally linked with an increase in the others. With respect to plant scale, there is much evidence that as the size of the plant increases, so unit costs of production have historically tended to fall.[12] Whilst in principle smaller efficient plants could be built, in reality these have been neglected in favour of enhancing the efficiency of the larger ones. In many sectors, therefore, small-scale plants are no longer to be found, and this has been one of the 'windows of opportunity' which the AT movement has begun to explore. At the same time as this has occurred so there has been a consistent tendency for the concentration of ownership (reflecting firm-size) to increase. In the UK the proportion of net manufacturing output accounted for by the hundred largest enterprises rose from 16 per cent in 1909 to 24 per cent in 1935 to 38 per cent in 1958 and to just over 40 per cent in 1970. Concentration in the USA rose in a similar manner over this period (although to a lesser extent), that is from 22 per cent in 1909 to 33 per cent in 1970.[13] And product economies of scale increased as standardized output was produced for ever-larger markets. The simultaneous increase in these three dimensions of scale reached their ultimate logic in the production of 'world products' by 'world firms' (that is, TNCs) in 'world factories'.

A number of different reasons have been adduced to explain the tendency for a consistent increase in these dimensions of scale. Pratten lists seven as being of particular importance:

- indivisibilities such as the minimum effective levels of scale of particular sets of machinery
- economies of increasing dimensions; for example when volumetric increases are greater than those in surface area (see pp. 144–5)
- specialization of labour, machinery and suppliers
- economies of massed resources, that is, 'the operation of the law of large numbers' which diminishes risk and facilitates smaller inventories
- the ability to utilize superior technologies, for example, in the transition from batch to flow production
- learning arising as a consequence of larger size and longer experience, and
- the ability to control markets to reduce uncertainty and optimize producton

It is significant that although Pratten (and others, including Silberston) also list a series of diseconomies of scale — notably getting to the edge of

Figure 6.1. *Scale in production*

Woodward's classification	*Nature of activity*
A Discrete products	
Unit- and small-batch production	Production of units to customer requirements Production of prototypes Fabrication of large equipment in stages Production of small batches to customers' orders
Large-batch and mass production	Production of large batches Mass production
B Dimensional products	
Process production	Intermittent production in multi-product plant Continuous flow production in single product plant

Source: Adapted from Woodward (1965).

technical knowledge, control loss with large managerial numbers, in labour relations and in distribution [14] – until recently these have been given little prominence in the analysis.

Another important gap in emphasis in these classic studies of scale economies is their lack of systematic distinction between different types of industries. In so far as particular types of scale economies have technological roots, and in so far as these underlying technological parameters are now changing, this is a significant issue. Here it is the industrial sociologists and engineers who have offered useful concepts, distinguishing between two types of process and various types of industrial organization (Figure 6.1). The process difference is that between the production of discrete (sometimes called integral) products, that is those products produced as individual separate items, and dimensional products (produced in units of volume, capacity and weight). The relevant industrial organization difference is that between very specific, 'bespoke' products, and those made in almost infinitely large numbers. While this suggests a continuum of possibilities, it tends to find expression in production systems which are geared either

towards one-off/small-batch production, or to mass production. These industry differences have direct relevance to changing parameters of scale, as will become clear in later discussion (pp. 148–154).

In assessing the likelihood of emerging changes in the determinants of scale, it is useful to elaborate briefly on the views of Pratten and others and to flesh out the discussion on three of the major determinants of scale economies: the distinction between direct and indirect costs; scale economies in process industries; and the evolving dominance of the mass-production ethos. These are chosen since in one way or another they are all being affected by the new production technologies and organizational forms to be discussed below (see pp. 149–151). As the discussion proceeds, the implications which these changing determinants have for the three dimensions of scale will be highlighted.

Direct and indirect production costs

Direct production costs are inputs such as machinery, labour, energy, raw materials, components and buildings. Some of these costs are variable, in the sense that they are generally used in a constant relation to output; that is, any increase in output requires an equivalent increase in these inputs. Raw materials, components, labour and energy are generally the major elements of variable costs.[15] The second major constituent of direct costs are those which are lumpy and fixed, especially machinery and buildings. Although these items are directly used in production, they have to be accounted for whether the plant is in operation or not. Clearly the greater the degree of their utilization, the lower unit costs will be, and this category of fixed, direct costs is one of the main determinants of plant economies of scale.

A number of factors will determine the rate at which these fixed costs are utilized. Assuming that sufficient demand exists, unit fixed costs will be minimized if machine downtime is kept to the lowest possible level. This will be determined by the constant availability of adequate quality components and raw materials and by the reliability of the machinery itself. Perhaps more importantly, machine downtime is kept high if changeovers are limited, since the constant resetting of machinery will lead to production losses. Here there tends to be a link between high fixed capital costs, large-scale plants and undifferentiated final products.

If direct production costs (and, more specifically the fixed elements of direct production costs) are one of the major underlying factors for plant economies of scale, indirect production costs are crucial to the emergence of firm economies of scale. These indirect costs comprise activities which lie in the background of actual production. Whilst they are not generally used up in the process of physical manufacture, if they are not sustained at some general level, then the enterprise as a whole will not be able to function competitively. Historically, a limited number of indirect production costs have stood out in significance: the most important has been R&D such as that involved in long-run product improvement and development, and this clearly varies in importance between sectors; a second indirect cost of importance is management, not so much the detailed (junior) management of line production (which is more like a variable cost), but more the overall strategic planning activities of middle and senior management; third, is the function of raw material and component acquisition, storage and management; and the final major indirect element of total costs is that of sales and marketing.

These distinctions between direct and indirect, and between fixed and variable costs provide insights into the technological underpinnings of scale economies. Production processes which require a great deal of time to reset for different product specifications (such as that involved, for example, in changing patterns of weaving looms) will in general be associated with the need to specialize production, and hence necessarily involve the production of particular products, generally on specialized lines or in specialized plants. On the other hand, those process and product technologies which make heavy use of indirect inputs (for example, they may require a great deal of marketing, or be very technology intensive) will provide scale economies for large firms who are able to spread these costs over a large number of plants. As will be seen later, the trend over the past century has been for both of these categories to grow simultaneously, and so have plant- and firm-scale economies. The extent to which product-scale economies have been dominant has tended to reflect the problems involved in resetting machinery which, as will be seen, is not only a physical and technical issue but also one affected by the underlying management philosophy.

The process industries

A distinction has been drawn between dimensional and discrete products. The former was defined in relation to the constancy of its output-specification. Often, this category of dimensional products is conflated with the less-easy-to-define category of process industries since these industries most generally produce uninterrupted flows of output. The problem is that this apparent flow in process industries may, on detailed inspection, comprise different batches, and this will have implications in the production processes for the resetting of machinery specifications. Hence Woodward (1965), who was primarily concerned with the nature of productive organization, felt that the clearer distinction was to be made between dimensional and discrete industries, rather than between process and non-process industries.

What then are process industries, and do they have inherent scale economies in production? As their name implies these industries can be most easily characterized in terms of the necessary completion of chemical reactions in production. This requires a carefully controlled environment — the process may be completed in either a continuous form (with a constant flow of inputs and outputs) or in the form of separate batches. It is out of the

necessity to control chemical reactions that scale economies in production arise, and this appears to be directly related to the inherent nature of volumetric space.

Briefly, controlled production requires enclosed containers; the geometry of volumes is such that increases in internal capacity do not occur in the same relation as increases in external surface — in fact the relationship of change in surface area to volume is around 0.6. Over the years process plant engineers noted a rule of thumb that as they doubled plant capacity, so construction costs only tended to increase by about two-thirds. They have come to refer to this as the '0.6 rule', based on the understanding that in these industries volumetric processes are dominant.[16] Here it is possible to see a close internal dynamic to plant economies of scale in production. The degree of product-scale economies is unrelated to this '0.6 rule' but instead reflects the ease with which particular processes can be switched to different batches. Firm-scale economies are also variable in the process industries, depending upon the intensity with which indirect costs are involved. It should be said, however, that process industries tend to be highly technology intensive, and in fact it was to meet the needs of one of the first process industries, that of sugar, that the first school of chemical engineering was established in Audobon in the USA in the nineteenth century.

The mass-production ethic

The ethos of mass production is now overwhelmingly dominant in most of the IACs. Despite the fact that batch production continues to play a prominent role in modern industry, Charlie Chaplin's unforgettable experience with the automated production line and the dentist's chair in his film *Modern Times* continues to dominate most of our perceptions of production in the modern factory.

Whilst the mass-production line was first developed in the nineteenth century in the USA in the armaments, cigarette and canning industries, it became the dominant production technique only in the early twentieth century.[17] This was as a result of two major factors: the growth of the school of 'Scientific Management' (largely following the precepts of F W Taylor) which was closely bound up with the professionalization of engineering and the establishment of the Society of Mechanical Engineers in the USA in the 1890s; and the demonstration effect of Henry Ford's mass-production line, and the consequent stimulation of consumer demand and supplier industries. That this form of production reflected the unique characteristics of the US, heavily conditioned by a shortage of labour and the relative absence of a craft tradition, became shrouded, so that the belief that mass production equalled efficiency was almost universal. It became the 'ideal type', the model to be pursued by all industries even if they were ultimately constrained by the small-batch nature of demand. So instead of factories striving to reduce changeover costs and increase the flexibility of small-batch production by producing near the final market, the alternative of specialization via production in dedicated lines became dominant. The inevitable consequence was the growth of large-scale factories at the site of least production cost, and the shipping of output to the site of final demand. In the most recent period, this specialization has occurred on a global scale, with 'world factories' producing components for assembly elsewhere.

A particular set of organizational patterns associated with this mass production ethic involved the specialization of production. In relation to factory layout it led to functional patterns of production organization in which particular types of machines (such as welding) and processes (such as assembly) were grouped together. Work-in-progress traversed the shop-floor in a confusing and higgledy-piggledy path as raw materials were transformed into final product. In terms of work-organization, management followed the principles set out in Adam Smith's description of pin production. Individual labourers were tied to minutely specified tasks in the belief that they would become more dexterous at them, and that the time involved in changing from one task to another would be minimized. At the same time the work was increasingly deskilled to minimize wages and the power which workers might have to disrupt production.[18] Detailed control over the work-process was taken away from the line-worker and given to supervisors — the line was to be kept working at all costs, even if this meant faulty products. The cost of rectifying these at the end of the production line was considered to be less than the costs of interrupting production. (It was these factors which led Schumacher to rail against the inhumanity of contemporary working life.) Inventory lines were to be kept full, just in case anything were to go wrong, and suppliers were subject to the same organizational forms — in order to squeeze costs to a minimum, dual-sourcing and arms-length relationships were preferred.

Scale economies in the era of mass production

These three underlying determinants of scale, considered together with differences between industries, make it possible to identify more clearly the particular characteristics of the scale economies which have come to dominate over the past century. Figure 6.2 relates the growth of scale economies in the three major forms of production organization — small-batch discrete products, large-batch discrete products and process industries — with the three most important dimensions of scale economies — product, plant and firm. It can be seen from this that with the exception of much of small-batch production (where product scale is limited by the nature of final demand or technological factors — See p. 158), scale economies have tended to rise coterminously. Not only have undifferentiated products come to be the norm, but so have individual production lines and plants. The consequence

Figure 6.2. *The technological trajectory towards scale economies over the past century*[a]

Dimensions of scale economies Type of industry	*Product economies of scale*	*Plant economies of scale*	*Firm economies of scale*
Small-batch discrete products	static	varies by sector, but generally static	varies by sector, but generally static
Large-batch discrete products	growing	growing	growing
Dimensional industries	growing	growing	growing

[a] These are 'ideal types', representing central tendencies. There will obviously be variations, reflecting sectoral specificities, differences in corporate strategy and some differences between countries.

has been that most factories have been too specialized to meet the immediate market and final output has been shipped to distant places. Significantly this has often occurred when there are no inherent technological reasons why plants should produce on a large scale.[19] Product life-cycles have tended to be long enough to recoup these heavy expenditures on large-scale and dedicated production lines. Finally, partly because of the homogenization of final demand (representing heavy indirect expenditure by large firms in taste creation) and partly because of the growing R&D intensity of technological progress, firms have become increasingly large, such that a relatively small number of TNCs now dominate global manufacturing production.[20]

This drift towards the large scale has of course had important implications for the Third World. The development of 'world factories' has simultaneously had positive and negative effects: it has been to the advantage of those selected NICs who have had a role to play in international specialization, but for other DCs this has made production for export more difficult. In so far as local markets are concerned, the small size of their markets has often been in sharp contrast to the minimum effective levels of scale in many sectors, making it difficult to achieve low-cost production. This has had manifold implications: in the agricultural sector the absence of local production of implements, fertilizers and so on has inhibited the growth of output; linkages for the continued development of the modern industrial sector have been restricted; and the pattern of unevenness of development within many DCs, favouring concentrated production in enclaves at the expense of decentralized development, has been exacerbated.

Factors inducing a change in optimum scale

A large number of analysts now acknowledge that since the early 1970s the IACs have begun the process of transition to a new pattern of growth. As explained in Chapter 1, this represents a departure from the pattern of economic and social development which emerged over the past century, especially since 1945. Naturally, as with any attempt to characterize such a complex terrain, there are a number of different views on the nature and significance of these changes. There is also some difference of views on what constitutes the 'new order'. Nevertheless there is fairly widespread recognition of a number of the more important components of transition: a change in market preferences from standardized to differentiated products; the introduction of new forms of managerial orientation and work organization; the diffusion of systemic electronics-based automation technologies; and the development of new forms of inter-firm linkages.

All of these have important implications for optimality in each of the dimensions of scale. It is relevant, therefore, to consider this in somewhat greater detail, beginning with a discussion of consumption patterns, organizational factors and flexible manufacturing technology. Since these changes are only in embryonic form, conclusions can only be drawn at a general level.

New preferences in consumption

As Henry Ford showed, by producing standardized products, and selling them in a standardized form to 'standardized customers', production costs were lowered and markets were expanded. But as the basic needs of consumers were satisfied, and as incomes rose in the IACs, so consumers became more demanding. Moreover, as market conditions became more competitive, producers played an active role in fostering consumer dissatisfaction with unchanged products. As a result, the last two decades have seen a significant change in consumer preferences in the IACs. Price is now less important than quality and novelty.

This trend towards what is called 'niche markets' is not confined to final consumption goods such as autos, garments and consumer electronics. It also applies in intermediate products such as steel and chemicals. In both of these sectors differentiated products — special steels and fine chemicals — have become the areas of highest growth.[21] In microelectronics as well raw processing power — 'the most bits for a buck' — is giving way to greater flexibility and programmable microprocessors are the areas in which the greatest technological rents are to be earned. Applications Specific Integrated Circuits (ASICs) are considered to be the wave of the future.

These changes in consumer preferences often demand matching alterations in the technology of marketing. The 'supermarket' principle, which has been widely applied not just to foodstuffs, is being threatened by the growing differentiation of consumer preferences. Thus in both the UK and the US (where the principles of mass production are most firmly entrenched) sales of garments in large stores are being undermined by the development of specialist retailers. The attempt to apply these supermarket principles to other sectors, such as banking, appear to have had little success and firms such as Merrill Lynch have retreated from earlier plans to introduce 'one-stop financial supermarkets'.[22] As will become clear below, these changes in consumer preferences have not occurred autonomously and have been facilitated, and often fuelled, by simultaneous changes in production philosophy and technology which have made it possible to widen customer choice.

New forms of managerial orientation and work organization

The gains appearing to accrue from the introduction of mass production were phenomenal. Take the case of Henry Ford's early attempts to restructure his production system. In the case of magneto assembly, what had previously taken a single person 20 minutes was split into 29 operations with 14 persons assembling 1,335 magnetos in 8 hours. This represented a more than four-fold increase in productivity. The same principle was extended to the chassis assembly line, progressively reducing the labour content from 12.5 to 1.5 hours over six months.

So the principles of mass production were forged: factories laid out on a functional basis, dedicated lines, homogeneous output, just-in-case inventories, deskilled labour, specialized job-tasks, and control by supervisors. This was then extended to production in general with the expectation that the principles would be widely applied. The fact that this was not to be the case, and that in most of the engineering sector in the IACs around two-thirds of production occurred in small and medium batches, was generally swamped by the belief that mass production had triumphed. Where this was not the rule, it became one of the primary functions of management to redesign the organization of production so that the principles of mass production could be brought into operation.

But after a long period of growth this system ran into difficulties. It proved to be unwieldy, and required stable social environments which became impossible to maintain. It also became very costly. For example, the idea that tasks should be specialized led to quality control being relegated to the end of the production line. With complex and costly products, the ex-post rectification of errors proved to be very expensive. Moreover goods were often of a shoddy nature and were not sensitively attuned to changes in consumer taste patterns. (The experience of the US TV and auto industries is especially relevant here.)[23] Often, also, the functional layout of factories meant that work-in-progress was 'lost' for long periods. One British company reorganizing itself found that under the old system of functional layout, metal took 13 weeks to get through the plant (for a total processing time of less than 16 hours), travelling 3 kilometres in the process and involving the production of significant numbers of defective components.

Japanese 'total competition', in production technology and managerial efficiency, came as a devastating blow to this organizational paradigm. With the attempt to match Japanese quality, and then to reduce inventories, a managerial revolution began to sweep through Western industry in the late 1980s, beginning in the semiconductor industry. Just-in-time became the catch-phrase, quality circles were introduced, single-union agreements with flexible work practices were increasingly negotiated and suppliers were cajoled to co-operate. What is especially important is that after the initial misperception that 'Japanese work-practices' could be introduced into old-established systems in a series of discrete steps, Western management has come to realize that the real lesson to be learnt from the Japanese is the systematic and inter-related nature of these organizational changes, and the virtues of nimbleness and flexibility. These features of managerial orientation represent a profound change from the old mass-production order.

In order to achieve this flexibility, the central tenets in the mass-production system have to be overturned. Factory layout has moved from a functional basis to production manufacturing-cells, each of which possesses the range of machinery required in production. (The results of this reorganization have been striking — the British firm described above reduced its work-in-progress from 13 weeks to 12 days, with the metal travelling 80 metres rather than 3 kilometers and the defect rate being significantly lowered.) Instead of focusing on long runs of homogeneous output, the emphasis must be placed on frequent and rapid changes in product. This requires multi-skilled workers. In the pressing of body panels for autos, for example, the die-changing has traditionally been done by a specialized cadre of workers, and this has contributed to the time taken to change the tools. In the new mode it requires the same workers to operate the presses, to change the dies and in some cases to undertake elementary maintenance and repair tasks themselves. It also means that workers must become more actively involved in the production process and that they must be given some degree of control over it. This is especially relevant for quality control, since 'zero-defect' inventories are a prerequisite for just-in-time production.

These and other factors represent a fundamental reorientation of managerial perspectives, overturning a professional culture forged over nearly a century. There is no doubt that it is permeating rapidly, and that together with the introduction of flexible new electronics-based production technology, it will have a profound effect in transforming the inherited mass-production paradigm. At the same time, as shall be seen, it will have major implications for scale economies in production.

The significance of microelectronics-based automation technologies

It was not simply a clever phrase designed to capture the attention of the public that led Henry Ford to offer a Model T Ford in any colour as long as it was black. There were inherent technological reasons why this product specialization was desirable, and this was due to the desire to minimize downtime. The importance of this can best be explained through a number of examples. These examples are illustrative also of the interaction between the technological and organizational determinants of scale in production.

In automobile production, parts which are specific to particular models of cars require settings of machines, and these may take time to reset for different models. Take the case of body-panels, which define the outside lines of the auto. In general these are shaped by the pressing of flat sheets of metal in five stages, involving the exertion of between 300 and 500 tons of pressure. The nature of the final shape is defined by the 'dies' which are used. As can be appreciated, in order to translate this high pressure to the metal blanks, these dies are of considerable size and weight. Changing them can be complex and time-consuming — the production line has to be stopped and specialized die-changers called in to perform the task. In the mass-production paradigm this took up to eight hours, involving a considerable amount of idle machinery and workers. Inevitably, therefore, there was pressure to maintain the continuity of production, not just in the manufacture of body-panels but for other components and processes (for example, the colour used in the paint-shops) which were specific to individual cars.

A second example is that of the production of glass containers (such as tumblers and bottles) which involves a series of carefully-controlled operations. A precise amount of molten glass has to be extruded from the furnace into a carefully-positioned mould. The mould has to be manipulated in a series of steps involving the blowing of air into the molten mixture (to determine the internal dimensions of the container) and the formation of the top of the bottle, often requiring the defining of a screw-shape around the rim. These processes require precise control of the temperature of the molten glass, the positioning of the mould, the blowing of the air, the repositioning of the mould, the formation of a screw-top and the transfer of the final product to a moving line for inspection. The production of a different shape of container requires the whole process to be brought to a halt — it takes about two hours to change the moulds and to reset the timing of the machinery. As can be appreciated this manual resetting can only be approximate in a situation in which precision is vital and the consequence is generally that production occurs through a series of iterations. As a rule of thumb it is reckoned that machine downtime is around eight hours, two of which are for resetting and the remainder for iterative resetting. Not only are machines idle — the furnace requires refiring (for which fuel-use is disproportionately high) and waste products are produced during the iterative resetting of machinery.

A third example of the role which downtime played in reinforcing plant- and product-scale economies is that of steel rolling. Steel is made from molten material which is then produced in a series of final shapes to meet the needs of customers. This may involve flat sheets (used in body-pressing in the auto industry, as described above), bars or coils. Of course each of these forms has different tensile characteristics as well as different thicknesses, lengths and so on. In the case of the rolling of bars this involves the reception of molten metal and a series of rolling sub-processes during which the ultimate shape is produced. Changing the final specification requires the stopping of the rolling plant (and sometimes also the furnace) and the resetting of each of the stages of rolling. Again, as in the case of glass containers, the resetting is done manually and an iterative process is consequently required before acceptable output is produced.

From each of these examples it is possible to see the roots of scale economies in production. Changeover costs are substantial, involving machine downtime and spoiled output and the need to dedicate production to a particular product. In the case of automobiles, the general rule of thumb by the late 1970s was that plants had to produce 250,000 of the same cars a year, generally involving two separate lines, to reach the bottom of the cost curve. In the case of glass containers, production costs were minimized when machinery was dedicated to the production of a single type of container. The industry's ideal was a glass-forming machine producing a single type and size of container which was fed directly into a bottling plant situated on an adjacent site. Steel rolling occurred in specialized lines, often dedicated to the production of a single specification of metal. In each of these cases the minimum size of the line was set by the minimum scale economies involved in a particular sub-process, so that the inherent technological characteristics involved in body-pressing, for example, dictated that it would not be optimal to press less than a particular quantity of panels. Thus two sets of machines pressing 125,000 panels of the same type per year would cost less than 250,000 sets of machines producing one panel each per year. It was this factor that led to the definition of the optimal size of the assembly plant as a whole.

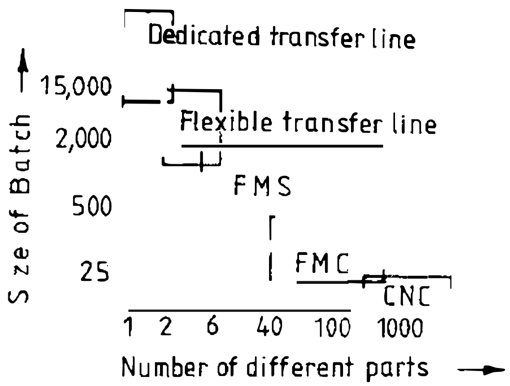
The link between these technological characteristics and the inter-firm division of labour is thus manifest. Bottles, cars, metal, beer and other products were each manufactured in a dedicated large plant in order to minimize costly machine downtime. Then, because in most cases the immediate market was too small to absorb this scale of output, the final product was shipped to consumers, even if they were at the opposite end of the world. Once this was being done, it was logical to locate the plant at the point of lowest labour-cost — perhaps using female labour in the Third World — especially as the abundantly available energy and state-provided communications infrastructure meant that communication costs were relatively low.

It is here that the significance of microelectronics-based automation technologies is to be found. Their flexibility and precision mean that many of the changeover costs which have underlain scale economies can be substantially reduced, and can sometimes even be eliminated. Consider, for example, the case of the glass-moulding machine described above. In the pre-electronic era, the precise timing mechanism consisted of a heavy metal cam, with a series of protruding switches each of which activated individual sub-processes. This was the type of mechanism incorporated in the musical-boxes of old, in which a rotating drum ('cam'), with protruding fingers, depressed extended metal 'notes'. In the same way that changing the position of the fingers on the drum produced a different tune, so changing the position of the activators on the cam affected the timing of the sub-process in the glass-moulding machine. With electronic controls the resetting of the activators is not just immediate, but also exact, so that downtime is reduced to mould changeovers; and there is little spoilage after resetting. The electronic timing mechanism is a small box — it used to require a reinforced floor, capable of holding a heavy rotating drum without distortion. In steel rolling new electronic controls are being introduced which make it possible to continually and precisely adjust the pressure exerted on the rollers and to rapidly change their size. Consequently, it is relatively easy to change the specification of the metal being rolled and plant flexibility is significantly enhanced. In autos new flexible die-changers allied to new work practices (which have in fact been more important) have cut changeover times from around eight hours to less than ten minutes. This has significantly reduced the cost of moving production from one model to another.

Increasing attention is now being given to the introduction of these flexible microelectronics-based automation technologies in a wide range of sectors. Whereas in the mass-production era automation was largely confined to dedicated production lines producing many variants of a single product, the reduction in changeover times (and the increase in precision) is now allowing the automation of medium- and small-batch production. It is also allowing mass-production lines to produce a wider range of products, in smaller batch-sizes. The technologies are still evolving and include flexible transfer lines (which allow for the alternative routing of work in progress), flexible machining cells (FMC, allowing for the machining of different parts), flexible manufacturing systems (FMS, involving the machining and assembly of different parts), and computer numerically controlled machine tools (CNC, individual stand-alone machines).

The relationship between these various flexible technologies and the extent to which they allow for the manufacture of many different types of parts produced at different scales is illustrated in Figure 6.3. It is instructive to compare these choices with the 'hard automation' of the dedicated production line.

Before considering the implications which these developments in flexibility have for the dimensions of scale, it is necessary to note one other emerging



Source: Bessant and Haywood (1985)

Figure 6.3 *Options in flexible manufacturing technology*

characteristic of the diffusion of microelectronics. This concerns the increasing importance of systems in automation technology, reflecting a combination of the introduction of similar machine-logic devices and convergent technologies.[24] The common use of digital electronic control devices in a wide variety of individual machines (ranging from word processors, through computer-aided design to numerically controlled machinery and testing equipment) allows them to be easily interconnected. For example, machine controls can easily be specified in the design stage, and at the same time the information can be used for stock control and publicity brochures. Convergence arises because of the common technological solution to the processing of information and its transmission between different workpoints. The consequence is that together with the drive towards flexibility, technological progress in the IACs is being geared to the reaping of systematic gains, rather than to increasing the productivity of individual stand-alone machinery. This has important implications for the viability of small-scale production in the capital goods industry in DCs.

Implications for the dimensions of scale

Thus the 'normal' pattern of technological and organizational change which characterized economic growth in the IACs for many decades has begun to change. Some of this results directly from technological change, such as the introduction of electronically controlled automation technologies whose flexibility provides opportunities to switch production between products and so reverse the tendency towards greater scale. Other changes appear to have

their primary origins in the domain of organization, such as changes in factory lay-out and in the nature of work. Yet other changes manifest themselves as social phenomena, but in part result from the possibilities opened up by new organization and technology. Consumer preference for more diversified products (which is inherently descaling of product runs, and often also has descaling implications for plant size) is an example of this.

Although these changes are still at an early stage, they are becoming increasingly pervasive. Their relative importance is likely to vary between sectors. Is it possible, therefore, to predict the likely impact of these changes on the three dimensions of scale? Given the embryonic nature of these developments, the discussion which follows will only really be suggestive of the likely pattern of descaling. For reasons which will be discussed, the degree of uncertainty is particularly high in relation to changes in firm economies of scale.

Implications for plant size

Not all of these developments have descaling implications, for in some sectors opposite trends are to be found. It is important therefore to separate out these two divergent trends in plant size. Before doing so, it is necessary to digress briefly into a discussion of definitions.

Plant size is an ambiguous concept and can be reflected in a variety of indicators — numbers of workers employed, the physical size of the plant, or the units of output produced in a given period of time. Each of these criteria raises an important concern. With the rapid capital-intensification of production, a falling or static labour force may at the same time be associated with a major increase in plant output. The same is true of the physical size of the plant and here it is interesting that one of the largest Japanese automobile-components firms has adopted a policy to reduce the average physical size of its plants by 3 to 5 per cent per year and to hold the size of the labour force constant. Simultaneously, through the use of new flexible electronics-based automation technologies it plans to increase output. It has adopted this strategy because it believes that 'smaller factories are happier factories' and therefore that this will facilitate higher productivity and better quality production.

The most common interpretation of plant size probably refers to the rate of output in a given period of time, and here an especially important conundrum arises for developing countries. Consider the notional case of the steel rolling mill described above, producing, say, 50,000 tons of steel per year. In the mass-production paradigm, there would be a series of plants situated around the country, or the world, each specializing in a single specification of rolled steel. In no single region would the local demand be sufficient to absorb the total output of each of the plants, so the result would be a complex transport system distributing the output around the affected regions. But with the introduction of the new flexible equipment, each of these plants might be able to produce five different specifications of the steel, either divided through the year into five sets of 10,000 tons, or in any combination of product specifications. In these circumstances, the local market would be able to absorb this diversified output, and there would be a much reduced need to export the final product. But is this a reduction in plant size? On the one hand the plants still produce 50,000 tpa each, so there has been no change. On the other hand, the flexibility of these plants means that it is now possible to introduce a new, flexible plant into a region (say a developing country with small markets) producing a range of products for the final market where previously the total market for any one of these types of output would have been too small to justify production unless a considerable proportion of output were to be shipped to other markets. In this sense, insofar as it could be said that scale economies prevented decentralized production in the old paradigm, it would appear that the new technologies are descaling in nature. However the impact of this new flexibility on plant scale might be described, there can be no gain-saying its overall effect on the location of production.

Reductions in plant size Broadly speaking therefore, it is possible to distinguish two different components of diminishing plant-economies of scale. The first is where plant size is falling in absolute terms, involving fewer people being employed, smaller physical size or reduced output. This is indeed occurring. For example, one of the major producers of pumps for the semiconductor industry currently serves the global market from a single plant; it is now setting in train a process whereby production will be split into three (and possibly in the medium-term, four) different plants. One will serve the east coast of the US, one the west coast and one Europe and Japan. (This latter plant may itself be divided into two, one being set up in Japan.) Interestingly, this transition to what the firm describes as a flexible manufacturing strategy involves a combination of both new electronics-based machinery and new managerial practices. It does not yet envisage the introduction of flexible manufacturing systems, which are widely recognized as being technologically immature. The second component of changing plant-scale relates to the mix of output. Here, as was seen in the case of steel-rolling, the scale implications are to be observed in physical space, relating to the economics of location rather than the absolute size of individual factories.

In addition to these technical determinants in each country and industry there are a series of macroeconomic factors which also have an important bearing on optimum plant size. The power-generating industry is an important example of how changes in the legislative environment complement technological factors and lead to a reduction in optimal plant size.[25] Traditionally this sector has been seen as a natural monopoly and in many countries is served by a large nationalized utility. In many cases these utilities

have suffered from the same fixation with 'giantism' as Schumacher observed of the British National Coal Board. Large-scale plants generating 600 MW to 1,000 MW and costing billions of dollars have been constructed on the assumption of a rapid growth of demand. Yet whereas demand growth in the IACs used to average 7 per cent a year in the 1950s and 1960s, it fell to around 3 per cent during the 1980s and the likely future growth will be in the region of 1 per cent. Thus, as demand increments get smaller, very large-scale power stations will necessarily face idle capacity until demand catches up with these large increments in supply. High interest rates have also been seen to increase the cost of this idle capacity, while new technologies have emerged which reinforce the virtues of small-scale production. These include cogeneration (using waste heat to generate electricity), which can be operated to satisfy the needs of individual manufacturing plants, and combined-cycle gas turbines which are reliable, relatively cheap, quick to build and allow for a choice between different machines, thus enabling utilities to reduce their risk.

Perhaps, more importantly, changes in the legislative environment have also had an impact. Small-sized plants tend to be less disruptive and are thus less prone to delaying public enquiries. In the US the Public Utilities Regulatory Policy (Purpa) of 1978 was enacted to encourage energy saving by allowing small-scale cogeneration plants to sell electricity to the public utilities at the same price (the 'avoided cost') as it cost the utilities to produce the electricity. One decade later 3,720 small-scale Purpa generators produced more than 62,000 MW of power, equivalent to 9 per cent of the US's generating capacity (or the whole of the UK's).[26] Thus in the US these Purpa generators and a range of new investments in plants less than 200 MW are becoming of increasing importance. Similar trends seem likely to emerge in the UK as its power utility is privatized, although the extent to which smaller-sized plants flourish will depend on the precise provisions of the legislation.

The demise of the nuclear power industry in many countries, especially the US and the UK, is a particularly telling example of the dangers of giantism. Held to have great economic advantages, these large-scale generators have suffered not only from environmental hazards, but also from unanticipatedly long gestation periods. Consequently, and in view of their very high capital costs, they have proved to be highly uneconomic — in the UK their unit generating costs in 1989 were approximately three times those of thermal power plants, and the programme of expanding the number of nuclear power plants was brought to an end.

Increases in plant size Earlier in this chapter, a matrix was constructed (Figure 6.2) in which the three dimensions of scale (plant, product and firm) were set out in relation to types of industry (small-batch discrete products, large-batch discrete products and dimensional). It was argued that where it was possible to specialize production, large-scale plants resulted because changeover costs could be reduced. But three types of industry have avoided these growing scale economies. The first are those industries in which demand is by its nature heterogeneous, specified for the needs of individual customers. The major industry encountering differentiated demand is that producing capital goods where plant and equipment are often fabricated for individual users or for a small group of firms. By contrast, the intermediate goods industries (cement, steel, semiconductor components), the primary sectors (minerals and agricultural products) and the consumer goods sectors (with some exceptions discussed below) fit into the category of large-batch standardized (and hence automated) production.[27] A second example of heterogeneous demand is the handicrafts industry where the individualization of each product is an important product-attribute and large-scale production is ruled out almost by definition. The third industry in which small-scale production has predominated is where automation was prevented for technological reasons. This has been the major factor limiting the growth of large-scale production in the garments, shoes and leather goods industries since it has hitherto proved to be nearly impossible to automate the assembly of limp materials.

It is in the category of small-batch production that the new flexible electronics-based technologies are having a major impact. Essentially, in the pre-electronic era the customization of final output was achieved by using highly flexible and generally cheap machine tools, with machine specifications continually being reset manually. The consequence has been that for much of the time — 70–95 per cent by one estimate in the USA[28] — machinery stood idle. Since these capital goods were relatively cheap, the costs of this low utilization rate could be contained and the barriers to acquisition were low. By contrast, the automation of small-batch production involves the introduction of costly equipment; and plants in these sectors become large to justify the investment. (This represents an increase in the fixed component of direct production costs discussed in earlier sections — see pp. 143–4.) Here it is possible to observe a plant-scaling tendency in production, in direct contrast to the descaling tendencies discussed above. This involves not just the enlargement of the scale of plants, but also the diversity of products, since these new electronics-based flexible technologies work best with 'families of parts', that is when utilized to manufacture products which are similar to each other.

These developments create considerable problems for the capital goods industries in the Third World. These small-scale workshops will come under increasing competitive pressure, both in global and domestic markets. The continued viability of groups of such enterprises, such as the well-known Oklah industrial estate outside Delhi which is renowned for its small-scale production of machine-tools for world markets, must be open to question. Additional pressures on these small-scale plants will be exerted by the advance of systematic technologies in the IACs. Here it is the capability to

provide the whole package of capital goods, integrated through the widespread use of electronic control systems, which will determine competitive survival in the future. There are reasons to believe that the mechanical engineering industry will evolve in the same way that process-plant construction has come to be dominated by large integrating firms offering turnkey plants. This has already begun to emerge in the IACs. In the automobile industry, for example, production lines for engine manufacture used to be put together by the auto firm itself buying individual capital goods from a variety of small-scale firms. By the late 1980s they were acquired as a package, assembled by specialized large-scale capital goods firms.

A similar process of plant enscaling is beginning to occur in the garments industry, and this is of course a major problem for small-scale enterprises in developing countries. The final assembly of the limp cloth is still difficult to mechanize, although much progress has been made on the automation of in-plant materials transfer and stock control. Over the past decade major changes have been made in the pre-assembly phase, with the introduction of computer-controlled design, grading and cutting technology. This replaces a process which used to be undertaken manually with a drawing board, cardboard and a sharp knife. From a modest almost purely labour-intensive process, the industry is being increasingly transformed by the diffusion of new pre-assembly equipment, costing up to $500,000. This increase in the fixed component of direct costs is thereby forcing plant-scale economies into a sector which has traditionally been small scale in nature. Similar trends appear to be occurring in the case of the shoe industry.

The effects of these developments on DCs, especially those with low per capita incomes, are likely to be adverse. Textile, garments, shoes and leather products account for between one-third and one-half of all Third World manufactured exports, and for a much higher proportion in the lower income countries. In most cases production of these products has taken place in small-scale plants. The potential employment implications are significant here, since according to one estimate, around 10 million people are directly and indirectly employed in the textiles and garments industries alone in developing countries.[29]

Implications for product scale

The precision and flexibility offered by new technologies and by changed managerial perspectives is leading to major changes in the pattern of product technology, both with regard to the variety of products being offered, and the lead-time with which they are produced. In most cases the consequence is one of descaling, with product runs being shorter and time-horizons reduced. These effects are being felt across almost all industries. Some examples should give a flavour. In the garments industry, the size of production runs is declining and, simultaneously, the number of seasons is increasing and quality is being upgraded. In part this reflects an innovative response to escape competition from low-wage DCs. But it is being facilitated by new electronics technologies, especially in design, cutting and grading, and new forms of organization and management. New computerized equipment saves not only labour and cloth, but also time in the calculation of different-sized patterns and the cutting of cloth, and allows for a substantial increase in the variety of designs which can be produced. The new information technologies also allow for a more rapid response to changes in market demand.

These new automation technologies have been used by the Italian firm Benetton to develop a rapid-response system to production organization. Widespread use is made of networked electronic point of sales terminals in all their shops throughout Europe. This information system is linked to inventory control in one of the most automated warehouses yet built. This is so flexible that before the goods are delivered their labelling and price tags are made out in the language and currency of the country in which they will be sold. Computer-aided design equipment is linked to this careful control over marketing trends so that it is possible to adjust rapidly to the minutest change in demand, adjusting colour-shading, or product mix, or developing new designs as appropriate. Production itself is undertaken by a large number of independently owned sub-contractors who receive regular instructions and design updates from the Benetton offices. This system represents one possible direction which the flexible manufacturing paradigm may take and illustrates many of the points which have been made above (pp. 151–4). It shows firm-scaling characteristics, in that through these innovations (which have required extensive indirect production costs) Benetton's share of the Italian knitwear and jeans market rose from 1.8 to 6.8 per cent between 1978 and 1982. It also shows some plant-descaling characteristics in production since Benetton has introduced an extensive system of small-scale subcontracting.

In the automobile industry, the introduction of the new electronics technologies has led to a rapid shrinkage in the time required for model development. This used to take 6–8 years but has recently shrunk to 2–3 years. Much of this is due to the use of computer-aided design (CAD), a technology with widespread application in other sectors. It also follows from the flexibility of production equipment — in the case of the British Rover Group's engine plant which was completed in 1989, the development lead-time for the new K-series engine was halved since it was no longer necessary to first build and test the engine before the (dedicated) production line was constructed. Because the new technology is flexible, it was possible to begin constructing the production line before the engine design was complete, with the confidence that any of the design changes required could have been incorporated in the final plant.

The Japanese have become the major exponents of these product-descaling strategies in the automobile industry (and other sectors). Figure 6.4 illustrates their relative performance in a number of important areas of scale. In

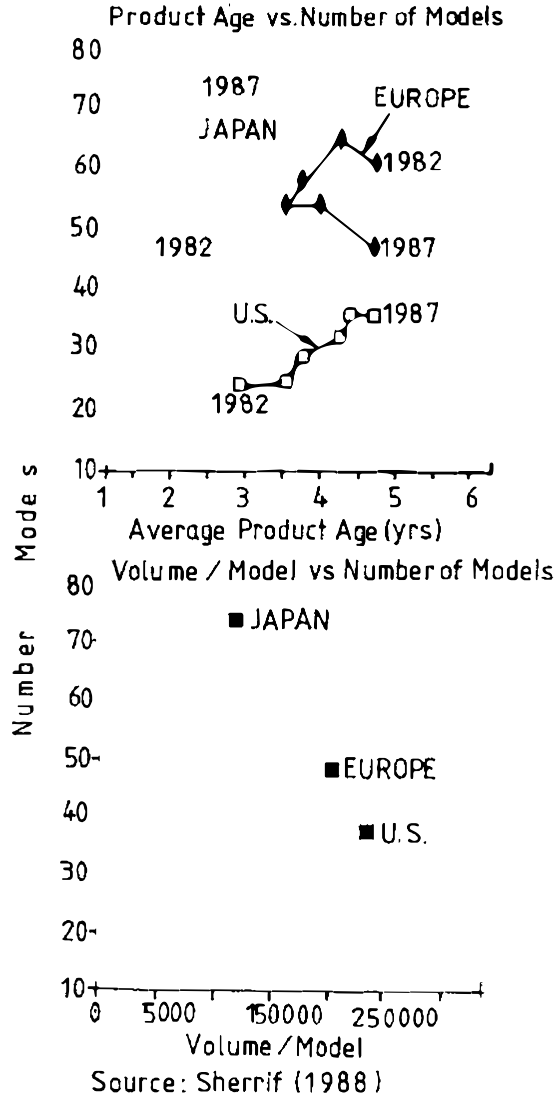


Figure 6.4. *Product economies of scale and economies of scope in the automobile industry*

Figure 6.4a it can be seen that compared to other manufacturers, their product-age is much lower (reflecting a decrease in product-development lead-time) and the number of variants which they offer is much larger. From Figure 6.4b it is clear that this is not a consequence of their higher output allowing greater product diversity in large-sized production runs, but directly because their model product scale is much lower than the volume producers in Europe and the US.

These examples not only reflect reductions in product economies of sale, but also show the interaction between changes in plant and product-scale factors. This has especially important implications for developing countries. In both the garments and the shoe industries, the economics of location are dictating that production occurs near to the final market. At the same time, in the garments, shoes, consumer electronics and automobile industries the increasing incidence of protectionism means that the politics of production are reinforcing this change. This is shown graphically in the case of two Hong Kong garments firms which have relocated from their home base to the UK,[30] and have done so by using the most modern automated equipment. In part this is to get access to the European market, but it also follows the need to be able to respond rapidly to market changes. Similar trends are evident in the automobile industry.[31] Ultimately, apart from those particular sectors where automation is leading to an increase in plant scale, the effect of these product-descaling factors is likely to be felt on both product and plant scale, with a larger number of factories being built around the globe, each designed to meet local demand with flexible production associated with rapid changes in product.

Implications for firm-scale economies

In order to understand the significance of the changes occurring in firm-scale economies, it is necessary here to refer to the earlier differentiation drawn between direct and indirect costs of production. The larger the fixed component of direct costs, the more significant were plant economies of scale. On the other hand the larger these indirect costs, the more substantial were the 'economies of massed resources', that is, firm economies of scale.

There is a variety of indirect costs underlying production, of which four stand out in importance:

- R&D
- middle and senior management
- the acquisition of inputs
- the marketing and sale of outputs.

Of these, there is no special reason why the third and fourth items should be changed by the new technological and managerial systems sweeping through the IACs. In the case of middle management, there is now considerable speculation (and some evidence) that computerized information technologies

reduce the need for intermediate levels of management.[32] Another factor militating against the growth of firm-scale economies is the tendency of large firms to be more bureaucratic and for innovation to be greater in new small firms. It is not clear how culturally specific this tendency is, since whilst it has been of considerable importance in the US, the rapid rate of innovation in Japanese and Korean firms seems to have occurred within very large (and growing) combines. In addition, Siemens, the largest West German firm, seems in recent years to have become the dominant European innovator in many sectors.

But these firm-descaling factors must be set against the simultaneous increase in the research-intensity of production and the growing market-intensity of sales. By the late 1980s these had speeded up considerably and became one of the most important characteristics of modern production. As such they dwarf the scale-diminishing implications of a reduced role for middle management. There are a variety of different ways in which this growth in R&D and marketing intensity are finding expression in the expansion of firm economies of scale. One immediate impact is that it is strengthening the role being played by TNCs in many sectors. This is becoming especially important in the chemicals and agricultural sectors as the biotechnology revolution is beginning to penetrate production. One recent study provides evidence for this and forecasts a major trend towards the appropriation by these TNCs of technological advance in agriculture.[33] Another expression is the growing power of global brands in determining market-share, in DCs as well as in the IACs.

But there are also other ways of diffusing indirect costs which do not have the same implications for firm-scaling. One possibility arises from the ability to swap technology, although this often involves TNCs. This is now an entrenched phenomenon in the global electronics industry in which technology licensing is induced less as a reason to maximize revenues from technology generation than as a means of obtaining access to the technology of rivals.[34] It is a process also sweeping through the aerospace, military, automobile and commercial vehicles sectors and is likely to become equally important in all other sectors in which the technological intensity in production is growing. Candidates here include the garments industry, of especial relevance to small-scale firms and household producers in developing countries.

Co-operation between small firms who share indirect costs of production is another alternative to the growth of large firms. This is probably at the most advanced level in what has come to be called flexible specialization.[35] In this, small firms collaborate and share those indirect costs such as marketing, design-intelligence and R&D which underlie the growth of large firms. This has become a particularly prominent form of organization in parts of Italy where *consorzia* have developed, facilitated by new forms of legislation. These groupings of small firms have enabled Italy to become the world's largest net exporter of shoes, garments and furniture. In footwear the average size of firms is 17 employees (as against 110 in the UK); in furniture it is 5.8 and in garments 5.5.[36] Similar types of co-operation are to be found in West Germany. In Cyprus, the government reversed a long-running strategey aimed at encouraging the growth of large firms, and adopted one in which *consorzia* of small firms (modelled on those operating in Italy) are being encouraged.[37]

A related aspect of these developments in firm-size is the belief that co-ownership may be especially productive in relation to the new organizational and work forms which are emerging. (The discussion by Schumacher and other thinkers in the AT movement concerning the possibilities for co-ownership and the virtues of small business become relevant here.) The production lines being pioneered in Sweden and Japan reverse the historic tendency for control to be taken away from the production worker, and in many plants the line-worker has the ability to close down the line if he/she notices something untoward happening. In the context of the conflictual relations between management and labour which have emerged in the older IACs it is difficult to conceive of this autonomy being returned to the line-worker without extensive disruption occurring in production. (In Japan it is possible because the quasi-feudal social relations which exist there seem to inhibit workers exercising this control in contradiction to the wishes of management).[38] It is arguable that the only way in which the more 'democratic' western IACs can successfully institute these new forms of production is through the introduction of a more participative system of ownership and management.

In Figure 6.5 these emerging changes in economies of scale are summarized and contrasted with those which developed in the mass-production era. In relation to products, there appears to be a reduction in scale in the large-batch discrete products and the dimensional industries, but an increase in scale in the small-batch discrete products industries. In relation to plant size, scale economies are reducing in the large-batch discrete products and the dimensional industries, and rising in small-batch production. By contrast firm economies of scale seem likely to increase in each of these three major categories of industry, unless there is a more widespread movement towards interfirm networking (as in the Italian *consorzia*) or technology swapping.

Changes in scale and appropriate technology in the Third World

Modern industrial society appears to be poised at a transition from a highly specialized production system in which the emphasis has been on giantism towards a more systemic and flexible paradigm. It is not yet clear how extensive these changes in scale will be, nor how these might be distributed between sectors, regions and countries. In part this uncertainty arises from

Figure 6.5. ***The three dimensions of scale in the change from mass production to flexible production***[a]

Dimensions of scale	*Product*		*Plant*		*Firm*	
Type of Industry	Mass production	Flexible production	Mass production	Flexible production	Mass production	Flexible production
Small-batch discrete products	static	growing	static	growing	static	growing
Large-batch discrete products	growing	falling	growing	falling	growing	growing
Dimensional industries	growing	falling	growing	falling	growing	falling

[a] These are 'ideal types', representing central tendencies. There will obviously be variations, reflecting sectoral specifications, differences in corporate strategy, and some differences between countries.

the inherent lack of predictability of these developments and in part because we are still at the early stages of this process of change; it also reflects the fact that social and political processes will be involved in determining the course of future events. As such there is no unique scenario which will unfold, nor is there a single pattern of social organization which will encourage the emergence of a more rational and humane system. Indeed it is precisely this latter factor which opens the space for policy action in the AT movement. Alternatives do exist, and it is important that they be shaped in socially meaningful ways.

From the point of view of the Third World the need to shape these emerging technologies assumes even greater importance. This is not just because many developing countries face an urgent need to improve the living conditions for the mass of their populations, but also because the new paradigm offers particular opportunities for development, especially in so far as it reduces the scale constraints to production. Moreover, because many developing countries have not had decades of commitment to the outmoded mass-production paradigm, they may well be able to make the transition to a new order more successfully than can the mature industrial economies of North America and Europe. The underlying changes also pose some threat. Left to market forces in the IACs the Third World's historic pattern of dependence on inappropriate technology may continue.

There are four major areas in which descaling holds promise for AT in the Third World:

- to meet the needs of the modern sector, where continued economic growth is being hindered by underutilized capacity and by shortages of material inputs. High minimum effective scales of production in the context of small markets have led to monopolistic market structures and unequal patterns of development, while the capital intensity of these inappropriate large-scale technologies has exacerbated the already serious employment problems prevailing in many economies;
- especially in so far as the urban poor are concerned, more appropriate modern-sector technologies may cheapen wage goods and perhaps expand employment;
- descaled technologies might improve the prospects for the local manufacture of inputs, with linkages not only to the modern sector in the urban areas, but also to the agriculture sector where the mass of the population is to be found;
- and new possibilities are being opened up by emerging technologies, such as in the case of the micro-hydro plants whose sudden viability is almost wholly explained by the development of electronic switching mechanisms. Basic needs may be met in previously unanticipated ways.

It is helpful therefore to put together these various types of concerns of the AT movement in the LDCs with the emerging trends of the new paradigm, conscious that there is no unique form which will necessarily emerge. This is done in Figure 6.6 — the columns relate to the emerging changes in the dimensions of scale, the rows to some basic concerns of the AT movement. It is clear that in general the expected reduction in plant size in the mass-production industries is beneficial to the cause of AT in developing countries since it encourages local production. Conversely the growth in plant economies in the small-batch industries is generally adverse, especially in relation to the capital goods sector (perhaps producing inputs for agriculture). Greater product flexibility and shorter production runs not only mean reductions in plant size, but also open new possibilities for tailoring goods to meet local needs and tastes. In the case of the expected growth in firm-economies of scale, the general effect is, as expected, negative for AT, especially if (local) small firms tend to choose more appropriate techniques than (foreign) large ones — but this will of course vary between countries and probably also over time.

This chapter has considered the prospects for AT in the IACs by focusing on emerging changes in economies of scale. After many decades in which there seemed to be an inexorable drift towards ever-increasing economies of scale, the picture has now become more complex. In many sectors, especially those mass-producing discrete products, optimum plant size is falling and product runs are becoming smaller. Economies of scope are substituting for economies of scale and this presents exciting prospects for more disaggregated

Figure 6.6. *Likely changes in the dimensions of scale and their implications for appropriate technology in the Third World*

	Changes in scale in the dimensions of			
	Plant size		*Product*	*Firm size*
	falling in large-batch industries	*growing in small-batch industries*	*falling*	*growing*
Industrial development in modern sector	positive impact on economic growth	negative as local production hindered	positive as more possibilities	negative if large firms/TNCs choose inappropriately or repatriate profits
Wage goods for the low-paid	positive as local production	positive as goods cheaper	positive if for low income goods	negative if large firms/TNCs choose inappropriately
Intersectoral linkages (incl. for agriculture	positive as local production easier	negative as local production hindered	positive as more possibilities	negative if large firms/TNCs have fewer linkages
Wholly new possibilities (i.e. technological blending)	positive as local production easier	negative as capital goods industry is less viable	positive as new products are developed	negative if large firms/TNCs do not relate to local needs
Balance of payments	positive as local production easier	negative as local production hindered	positive if more local production or exports	negative if large firms/TNCs import more or export less
Encouragement of small-scale or co-operative ownership	positive as entry barriers lower	negative as entry barriers higher	neutral	negative by definition

units of production and therefore for a decline in the optimum economic scale of social organization. (The social optimum has been lower than the economic optimum for some decades.) It is not surprising, therefore, to find that the business community has begun to question the trend towards giantism and to see the economic benefits of smaller scale which Schumacher and others identified many years back. It is also not only in the IACs that the economic benefits of this descaling are apparent and, if anything, DCs are likely to benefit from this even more.

At the same time as there are tendencies towards descaling in some dimensions and in some sectors, enscaling factors are being injected into others. This has particularly deleterious implications for DCs, especially those who rely on low wages for their comparative advantage. In addition, whilst both product and plant economies of scale may in general be reducing, two of the major factors underlying firm-scale economies (that is, R&D and marketing) not only shows no sign of diminishing but, if anything, are likely to increase further. These growing indirect costs may either be met by a further growth in firm-concentration or by more co-operation and networking between small- and medium-sized firms. There are no inherent technological reasons why large-scale firms should win through.

There is thus no inevitability about the positive outcome of these changes. Clearly they are suggestive of a generalized tendency towards descaling and for this reason the overall impact is likely to be beneficial. What is less evident is the extent to which these new technological opportunities will diffuse and at what pace. One possibility is that left to market forces alone, the prospect of profits will induce rapid innovation. But this may not necessarily be the case. Moreover, the inadequacy of the market mechanism may not be confined to these changes in economies of scale. These factors are considered in the following chapters.