3 Process Innovation

Although the focus for our study is product innovation, we do not wish to underestimate the importance of process innovation. By investing in new plant and equipment, firms can gain in terms of productivity, material utilization, quality or reliability. They can even gain the capacity to manufacture new products which would otherwise have lain outside their reach.

It has often been pointed out that process innovation may be particularly helpful or suitable for small firms, since by this means they can share in advanced technology developed by larger firms. The adoption of a proven process technology may also have the advantages of low risk and short-term payback. The limitation of depending upon investments in process innovation, however, is that any competitor can easily follow suit, removing the initial advantage gained from the investment. Whereas new products tend to put a firm ahead of its competitors, investment in available process technology merely brings a firm up to standard. From the viewpoint of regional development, nevertheless, it is important that the process technology used by local industry should be up to an adequate standard, since otherwise the region will cease to be competitive with other regions where investment in up-to-date technology is higher.

For the purposes of our study, a particular interest is how investment in process technology relates to product innovation. Some advocates of investment in process innovation have seen it as an *alternative* to product innovation, especially if it permits existing products to be made at lower cost. The reverse is also possible: if products can be given a new lease of life through modifications made at low cost, this may be preferred to investment in sophisticated and costly equipment. Finally, it could be that investment in new production equipment goes hand-in-hand with product development. This might take place simply because innovative firms are likely to innovate in numerous ways. Or, similar technical expertise may be needed both to introduce new equipment and to develop new products: this could be particularly true where the same technology, such as that of microelectronics, was involved in both. Or again, firms diversifying their product ranges may need new equipment to be able to make the different types of products.

We are also, of course, particularly interested in how the regions differ in their use of new process technology. For example, does Britain's Northern region compensate for its lower emphasis on product innovation through greater investment in equipment? Or does the East Midlands region, on the contrary, support its product innovation through superior attention to new processes?

Process investment: the overall picture

In the sample of British firms, the level of process investment was gauged through a series of questions. Firms were asked whether they used CNC (computer numerically controlled) machine tools; whether they used robots; whether they used microprocessor controlled equipment for the handling of materials or parts; and whether, apart from these items, they had invested in any other kinds of capital plant *during the previous five years*. A firm was regarded as a process innovator if it answered 'yes' to any of these questions.

By this standard, exactly the same number of British small firms in the sample were process innovators as were product innovators: 57 per cent. (It should be recalled, however, that our assessment of product innovation referred to the previous two years, not five as in the case of process innovation.) Table 3.1 shows that product innovators were *more likely* also to be process innovators than were those without new or modified products; but the difference was not a large one. In fact, 61 per cent of product innovators were process innovators as well, while 52 per cent of those without new or modified products were process innovators.

Table 3.1 Process innovation and product innovation

column percentages

	Product innovation Yes	Product innovation No
Process innovators	61	52
Process non-innovators	39	48
Base for percentages	*56*	*42*

The table shows that, on balance, product and process innovation tend to be mutually supportive. But the percentages can also be recalculated relative to the total sample, and then they show that more product or process innovation goes on separately than proceeds in a linked manner. Whereas 35 per cent of all small firms were both product and process innovators, 44 per cent were only product innovators or only process innovators; and this was divided equally between the two types of innovation. So there is clearly wide scope for firms to pursue product innovation *without* investment in new processes; and there is also scope for firms to invest in production equipment when they are *not* developing new or modified products.

The same figures also show that 8 out of every 10 small firms in the British sample had engaged either in product innovation or in investment in new production equipment, or both. That left one in five small firms with neither product nor process innovation.

In Chapter 2 we pointed out that there were different levels or degrees of product innovation, and showed that it is important to take account of these. Possibly the most significant distinction is between products involving microelectronic components, and those without microelectronics. Here we found a much stronger connection between product innovation and process innovation, as Table 3.2 shows.

Evidently, it was quite unlikely that firms using microelectronics in their new products could do without investment in new production equipment. In this sense, microelectronics was a particularly intensive form of innovation.

Table 3.2 Process innovation, and microelectronics in new products

column percentages

	Microelectronics in new products Yes	No
Process innovators	77	51
Base for percentages	*22*	*76*

Another important distinction is between product innovation in firms seeking to diversify their markets, and product innovation in firms not pursuing diversification. Here again we found a strong link with process innovation, although not as strong as in the case of microelectronics. Of the product innovators who were also diversifiers, 69 per cent were also process innovators. The details are shown in Table 3.3.

Table 3.3 Process innovation and diversified product innovation

column percentages

	Product innovation with diversification Yes	No
Process innovators	69	49
Base for percentages	*39*	*59*

A number of other analyses, which we need not show here, confirm the general point which comes from these findings. Process innovation tends to be the more strongly involved with product innovation, the higher the level or intensity of that product innovation. Conversely, where product innovation is of a relatively simple or basic type, it is less likely to be accompanied by investment in new process equipment.

Advanced production equipment

Our picture of process innovation can be improved by looking separately at the more advanced kinds of equipment used by small engineering firms, such as CNC machine tools, robots, and automated

Process innovation examples

Precision Ring Makers (PRM) made components to high specifications, largely for the aircraft industry. Its main development work was focused upon process improvements. It had developed low cost tooling techniques which resulted in great savings: for example, tooling changes for thin guage shims using conventional techniques cost about £4000, while with PRM's technique the cost was about £30. It had purchased CNC machines for milling and engraving, and was planning to network the CNC machines to its computer system so that programmes could be transmitted directly to production.

Fabrication and Assembly Company (FAC) was primarily interested in welding technology. A recent example of process improvement was the application of plasma cutting instead of drilling, in the manufacture of heat exchangers and plates. A flushing system to prevent the build-up of sludge in the air chambers of the water tables which were being manufactured, was also developed to assist the introduction of plasma cutting.

handling equipment. However, only one firm in the sample was using robotics, so our consideration of this topic was, from the point of view of small British engineering firms, rather premature. Our most substantial information concerns CNC machine tools.

CNC machine tools have come into wide use, despite their high initial cost compared to conventional machines, because of several advantages. They are capable of machining complex components to a high standard of accuracy and reliability. They also offer a faster rate of conversion, and a shorter change over time. This makes them particularly cost-effective when machining relatively small batches, as the majority of engineering firms are doing. But it should not be assumed that all engineering firms without CNC machines are backward; the advantages of such machines will not apply in the kind of work done in some firms.

Among the sample of small British engineering firms, 29 per cent (approaching one in three) were using one or more CNC machines. Twenty per cent of the whole sample, or two in three of those with any CNC machine, had two or more in use, while ten per cent of the whole sample (one third of CNC users) had four or more. Nearly all the CNC users had acquired at least one such machine within the previous five years, which indicates a rapid rate of adoption. In fact, other studies have indicated that once established in a firm, the rate of adoption of CNC machines grows exponentially[1].

Another way in which microelectronics can be applied to production is through the automation of handling equipment. This can help to overcome difficulties in the automatic handling or transfer of materials, components or assemblies, especially in batch production systems. It transpired that only 11 per cent (one in nine) of the small British firms were using microelectronics in this way. In addition, one or two firms were using microelectronics in specialized process applications, such as digital read-outs from existing machine tools, or computerized quality control equipment. However, it is evident that CNC machines were the major application of microelectronics to production equipment.

We accordingly focused on CNC machines in order to find out how microelectronics in process innovation fitted in with product innovation. Here a remarkable contrast emerged. On the one hand, small firms with microelectronics in their new products were more likely than the remainder to be using CNC machines. On the other hand, firms *not* developing new products or modifications were slightly *more* likely to be using CNC than the product innovators as a whole. So CNC seemed to be used in two opposite ways. Either it could be used to support the more advanced or intensive product innovations, involving microelectronics; or it could be used to give an advantage in the production of a product range which was not being altered. CNC was least often used in conjunction with the development of new products without microelectronic components. These findings are summed up

Table 3.4 CNC machines and product innovation

column percentages

	Level of product innovation		
	With microelectronics	Without microelectronics	No product innovation
CNC machines	50	9	33
Base for percentages	*22*	*34*	*42*

in Table 3.4.

At the beginning of this chapter, we posed the question of whether process innovation helps product innovation, or is used to substitute for it. In the case of CNC machines, the answer is 'both': but it only supports product innovation of the more advanced type. Conversely, investment in conventional equipment tends to support new products without microelectronics, and is not a substitute for product innovation. This makes sense, since conventional equipment would usually not have the competitive advantages of CNC machines from the point of view of reduced costs of small-batch production.

Computers: another kind of process innovation

The use of special control computers in machine tools is a particular application of the versatile technology of electronic computing. The use of general purpose computers can affect both the administration of an establishment and its production systems. It is the most flexible type of process technology, and because it is capable of performing such a wide range of tasks, should be applicable whatever the characteristics of a firm's production.

A similar proportion of firms in the sample (60 per cent) reported use of computers, as reported investment in production process equipment. Nearly all these users had put accounting or payroll applications onto their systems, and around half used the computers for stock control. These are the more standard or basic administrative applications. In addition, however, substantial minorities were using computers directly to support production. For example, 37 per cent of computer users (nearly one in four of the whole sample) were engaged in computer aided design. The details are shown in Table 3.5. This table also provides comparisons between the two regions: comment on

Table 3.5 Uses of computers, in total and by region

column percentages

	Total	East Midlands	North East
All with computers	60	58	63
Computer aided design	22	24	21
Centralized control of groups of machines	8	13	2
Integrated multi-stage process control	10	11	9
Production scheduling	16	20	12
Purchasing	30	27	33
Stock control	35	38	30
Accounts or payroll	52	47	58
Other	24	22	28
Base for percentages	*98*	*55*	*43*

the regional aspects will follow in the next section of the chapter.

The next question is whether computers tend to be used by the firms which have already been identified as process innovators, or whether they are equally (or more) used by non-innovators. The answer is, emphatically, that computer use and process innovation tend to go

The use of computers: examples

Precision Ring Makers (PRM) had made an extensive and exceptional investment in computers, and was using three 15 megabyte machines, with a large number of 'intelligent' terminals, linked into a local area network. All of the accounting functions were computerized, as were payroll, personnel records, and a wide range of administrative and recording functions concerning production. It was in the process of setting up a database for a computer aided manufacture (CAM) system.

Fabrication and Assembly Company (FAC) had used a microcomputer for six years. This was used to computerize the accounts, budgeting and payroll. It was in the process of purchasing a new system which would extend computerization to the preparation of quotations, stock records, and work scheduling and work control.

Farm Machinery Manufacturer (FMM) had purchased a computer aided design (CAD) software package, which ran on a microcomputer. This was regarded as an important aid to the design of printed circuit boards for its systems.

Incinerator Company (IC) had installed a minicomputer system in 1985. It was used for a range of administrative and financial procedures, and there were plans to extend this to the scheduling of projects and production control.

together. In fact, 75 per cent of process innovators were also computer users, while the corresponding figure was only 40 per cent in the case of firms without process innovation. However, firms with CNC machines were *not* specially involved in computer use, by comparison with process innovators lacking CNC. In fact, 71 per cent of CNC users also had general purpose computers, compared with 79 per cent of non-CNC process innovators. It could be that in some cases CNC reduces scheduling and control problems and makes computer production control less advantageous. But a simpler explanation could be that the capital cost of CNC machines leaves some firms too few resources to pursue computerization as well.

We saw that process innovation was weakly linked to product innovation, but strongly linked to product innovation involving microelectronics. The use of computers turns out to be much more clearly linked to product innovation than is process innovation, and the link is again strongest in the case of product innovation with

Table 3.6 Use of computers, and product innovation

column percentages

	Product innovation with micro-electronics	Product innovation without micro-electronics	No product innovation
Using computers	86	68	40
Base for percentages	*22*	*34*	*42*

microelectronic components. This is shown in Table 3.6.

Unlike process innovation in the form of production equipment, computers appear to be used relatively infrequently as substitutes for product innovation, and much more often as supports for it. This is a surprising finding. One might have thought that small firms lacking new products might turn to the economies that might be achieved through computers, as a way of remaining competitive. As the table shows, less than half of them do so.

Regional differences in process innovation

It was shown in the previous chapter that the small firms in the East Midlands sample were slightly more likely than those in the North to be product innovators, but that this difference grew larger as more difficult kinds of innovation were considered. Very much the same is found with process innovation, but the differences are *greater* than with product innovation. In the North, just under one half were process innovators, but this rose to 64 per cent in the East Midlands. And whereas just 12 per cent (five firms) in the North had acquired CNC machine tools, the proportion was no less than 42 per cent in the East Midlands. Furthermore, of the five Northern firms with CNC machines, four reported no product innovation, and could be thought of as using their CNC machines as an alternative to product development rather than as a support for it. Virtually all the cases of CNC being used in conjunction with product innovation came from the East Midlands.

As Table 3.6 has already shown, the small firms in the North were *not* more backward in using computers than those in the East Midlands. If anything, there was a slightly higher proportion of computer users among the Northern firms. This was probably the result of differences in size distribution between the two samples. Firms with more than 50 employees were almost twice as likely (in the whole sample) to be using computers as were firms with less than 20 employees, and the East Midlands had far more of the firms in the smallest size category.

In the East Midlands, however, there was the substantial minority group of product innovators with microelectronics, most of which also used CNC machines and computers. There was no corresponding group of product innovators with microelectronics in the North, and most of the small usage of CNC machines there substituted for product innovation rather than supported it. As a result, more than half of the computer usage in the North was connected with 'conventional' (non-microelectronic) product innovation, whereas the proportion in the East Midlands was one quarter. In the East Midlands, product innovation with microelectronics, investment in CNC machines, and the use of computers, seem to act cumulatively, and it is this which is missing in the North.

What limits process innovation in Britain

Since four in 10 of the British sample had no new or advanced production equipment, it is natural to ask what, if anything, had prevented them. Of course, it is also possible that firms with new or advanced equipment would have liked to invest more in this way: they too could have met constraints. So all firms were asked the question.

It transpired that just half the firms felt that they had been prevented from making changes in production techniques which they would have liked to introduce. These firms were also asked to explain what was preventing investment. The great majority put forward 'lack of finance' as the primary stumbling block to changes in production processes. To a much lesser extent, 'lack of demand' (that is, presumably, lack of a market payback for capital investment) was also mentioned as a barrier.

These replies stand in striking contrast to those concerning the reasons for lack of product innovation (see Chapter 2). Lack of finance was only an obstacle to product innovation for a single firm in the sample, while market demand was the dominant consideration.

This contrast between the obstacles to product and process innovation leads to important conclusions. The fact that the answers given to the two questions were so different must increase confidence in each set of answers being genuine. If it were simply a conventional response to put the blame for lack of progress onto lack of finance, then this would surely have happened both in the case of products and processes. So product innovation emerges as the low-cost (or easy-to-finance) alternative, by comparison with process innovation. And the idea that economically depressed regions can make themselves more competitive by investing in standard, off-the-shelf process technology becomes less plausible, because so far as small firms are concerned, such a policy is much more likely to run into a financing constraint than is the case with product innovation.

British and German process innovation compared

In the previous chapter, we saw that in the sample of firms from the FGR product innovation was virtually universal. The same conclusion, it turned out, applied to process innovation. Ninety percent of the German sample reported changes in their techniques of production, and the proportion using CNC machine tools was almost twice as high as in the British sample. (It must be recalled, however, that the average size of firms in the German sample was considerably greater than in the British sample; and this, together with the general limitations of both samples, means that we must avoid descriptive generalizations about British and German small firms beyond our samples.)

Because virtually all firms in the German sample were process innovators, comparisons can add little by way of explaining general differences between process innovators and non-innovators. However, the German study went further than the British one in exploring *reasons* for process innovation and in considering how far different *types* of product innovation were accompanied by directly linked changes in production methods. This information helps to develop understanding of some of the distinctions drawn with the British survey.

In the British case, we saw that there was a division between firms using process innovation in conjunction with product innovation, and those using it as, to some extent, an alternative. The nearest to this distinction among the German firms emerged from the objectives for process innovation which they expressed. Four objectives were given with about equal frequency, and only one of these was to change production techniques directly to support new products. The other objectives were to reduce labour costs, to improve production quality, and to increase the flexibility of production. In the region of Nordrhein-Westfalia (NRW) the objective most frequently stated was to reduce labour costs through process improvement. In Baden-Wurttemberg (BW), however, the leading objective was to increase the flexibility of production.

This fits in well with what is known of the background of these regions. NRW is a region of heavy industry which has long since reached its maturity. The pursuit of labour cost reduction through process investment is the normal response of firms which are working within mature, static markets: economists refer to this as 'capital deepening', since investment goes into cost reduction rather than into the expansion of output. In the BW region, however, with its newer and more dynamic industries, the dominant aim of flexibility would help firms to take advantage of new market opportunities which are continually arising. Such a difference of emphasis also lines up with the two German regions' different profiles of product innovation, described in Chapter 2.

Among the British sample, as we have seen, process innovation was particularly linked to product innovation involving microelectronics. In the German sample, similarly, the presence of microelectronics in the new products directly led to changes in production techniques. If the products had microelectronic components, then in 80 per cent of cases they were accompanied by changes in process at the time of introduction, and by subsequent changes in process (connected with the new designs) in 73 per cent of cases. Where the new or modified products did *not* involve microelectronics, the corresponding proportions of process changes were only 58 per cent (at time of introduction) and 48 per cent (subsequent to introduction).

Although using a different path of analysis, therefore, both the British and the German studies arrive at the same conclusion here. Microelectronics, itself a more intensive form of product innovation, also results in more intensive process innovation.

In the British survey, the use of CNC machines and of general purpose computers were separately analyzed. In the German survey, a single category was used to encompass CNC machines, and computers used in production (for computer-aided design, production planning and control, and so on). Some 60 per cent of the German firms possessed this technology, which would be referred to in Britain as CNC/CAD/CAM. Nearly all these firms made changes in production techniques directly to accommodate the introduction of new products. In the minority of German firms where CNC/CAD/CAM was *not* in use, new products were invariably introduced *without* accompanying changes of process. So the German findings illustrate the great gain in flexibility and freedom of product choice provided by advanced manufacturing techniques.

The main difference here from the British results was that there was no indication in the FGR of *advanced* equipment being used as an *alternative* to product innovation. This might be, in part, a result of the greater average size of the firms in the German sample. There was, in fact, a strong link between size and the use of advanced CNC/CAD/CAM equipment among the German firms. It may well be that the German developments in this respect were altogether on a different scale to those among the British CNC users.

Conclusions

Like product innovation, process innovation was widespread in our survey, and virtually universal in the German sample of somewhat larger sized firms. The survey shows, then, no lack of concern for, nor lack of progress in, process innovation. However, at least so far as the British firms were concerned, there were indications that capital investment in new production methods would be progressing further and faster if it were not for financing constraints. This was a clear and important difference from the position with product innovation.

The central question addressed by this chapter has been whether, or to what extent, process innovation supports and complements product innovation, and to what extent it acts as an alternative or substitute. The issue can be approached in rather different ways through the British and German results, but there is a broad interpretation which covers both cases.

Improvement in process technology *can* be pursued, to some extent, independently of product innovation. Where this happens, the motive is likely to be labour cost reduction or rationalization. A policy of this kind can be pursued either with conventional production equipment or more advanced (CNC) equipment; but the use of CNC in this role was essentially confined to some of the British firms, and rarely occurred in the FGR.

Much more striking, however, is the opposite pole of process innovation, where advanced production equipment and computers are used to support the introduction of new products involving microelectronics. If as we have argued microelectronics represents a more intensive form of innovation in the machine building industry, then we can clearly see that intensive product innovation and intensive process innovation accompany one another.

Elaborating on this conclusion, the German evidence particularly suggests that it is through increased flexibility, or range of adaptation, that the advanced process technology facilitates intensive product innovation. The key difference in process innovation between the BW and NRW samples was the focus upon flexibility in the former case, contrasting with the adherence to traditional cost-saving objectives in the latter. Similarly, the evidence from the British survey suggested that the *complex of product and process innovation involving microelectronics* (and including computers) was what most fundamentally divided the East Midlands from the North-East.