INNOVATION IN UK SMEs: CAUSES AND THE CONSEQUENCES FOR FIRM FAILURE AND ACQUISITION

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Abstract

Using a specially constructed panel database, we analyse the links between innovation, survival and various aspects of business performance. The role of innovation is examined in the light of a model originally proposed by Downie (1958), and developed by Metcalfe and Gibbons (1986) and Metcalfe (1994). The model postulates a two-way relationship between innovation, growth and performance at the firm level. On the one hand, a firm's technological innovativeness in one period is a primary determinant of its performance in the next. On the other, a firm's performance is an important determinant of its future innovative effort. Poor performance is a spur to taking on the risk and uncertainty of innovation whilst past success may lead to the pursuit of more conservative policies. The results do not provide clear support for the latter hypothesis, but innovation significantly reduces the probability of firm failure and increases the probability of acquisition. Earlier versions of this paper were presented at the 'Innovation Measurement and Policies' Conference in Luxembourg on 20-21 May 1996 and the 'Entrepreneurship, SMEs, and the Macro Economy' Conference at the Jonkoping International Business School, Jonkoping, Sweden on 13-15 June 1996.

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1. Introduction

This paper describes the extent and nature of innovative activity amongst small and medium sized enterprises (SMEs) in the UK in the 1990s. It also provides an analysis of the way in which it is related to the past innovative activity of these firms, their past performance and competitive environment. We also model the relationship between innovative activity, business failure, and acquisition, taking account of the firm's age, size and industry.

Our analysis makes use of a specially constructed longitudinal SME database compiled by the authors and their colleagues at the ESRC Centre for Business Research (CBR) and its predecessor the Small Business Research Centre at the University of Cambridge. Since 1990, the CBR has conducted three separate postal and telephone surveys covering a sample of over 2000 SMEs in the UK. Taken together the surveys provide a wide range of information on innovation inputs and innovation output, together with a variety of other aspects of firm behaviour and performance over the decade up to 1995. The questions asked to elicit information on the extent and nature of innovative activity in our sample are shown in the Appendix.

The analysis which follows focuses on innovative outputs, in particular on the respondents' own identification of whether or not they have innovated and the extent to which their innovation was new only to their firm, or to all firms in their industry, or to all firms in general. Our paper is therefore based on the 'subject' approach to measuring innovation rather than the 'object' approach (which focuses on the identification with hindsight of significant or major innovations based on expert opinion or technical literature surveys). We then relate this 'subject' based measure of innovative activity to other features of our sample businesses.

In the next section we present a description of our sample and of the surveys on which the empirical analysis is based. We also provide, using a mixture of probit and cross tabulation techniques, a description of the variations in innovative activity within our sample across businesses grouped by size, age, and industry. Given the paucity of systematic information on SME innovative activity in the UK at the firm level, this analysis is of interest in itself. It also enables us to compare the results emerging from the 'subject' approach with those based on the 'object' approach such as those for the UK from the SPRU database (Robson and Townsend 1984) or the SBA database for the United States (see Acs and Audretsch 1988); as well as with a recent 'subject' based study of product innovation in manufacturing plants in the UK, Germany and Northern Ireland (Roper et al. 1996). In addition it provides the necessary background against which we subsequently analyse the links between innovation, survival and various aspects of business performance. This analysis is carried out in section 3. There the role of innovation is examined in the light of a model originally proposed by Downie (1958), and developed by Metcalfe and Gibbons (1986) and Metcalfe (1994). Essentially, the model postulates a two-way relationship between innovation, growth and performance at the firm level. On the one hand, a firm's technological innovativeness in one period is a primary determinant of its performance in the next. On the other, a firm's performance is an important determinant of its future innovative effort. Poor performance is a spur to taking on the risk and uncertainty of innovation whilst past success may lead to the pursuit of more conservative policies. Such reasoning has been echoed by Nickell and Nicolitsas (1995) who model innovative activity as a response to business adversity in the presence of imperfect capital markets. It is also reflected in recent surveys of the empirical literature (see Geroski 1995; Wood 1995).

The results of our analysis have implications both for the role that SMEs may play in the innovative performance of the economy as a whole, and for their role in the evolution of market structure. In the latter area the recent literature has emphasised the role of small firm innovative activity in overall industry performance (Acs and Audretsch 1987, 1988, 1990; Audretsch 1995; Geroski and Pomroy 1990; Geroski 1995). These implications are briefly discussed in the final section which also provides summary conclusions.

2. The Surveys and Sample Characteristics

The first CBR postal survey of two thousand SMEs was conducted in 1991. It was designed to include approximately 1000 manufacturing SMEs and 1000 SMEs in business services[1]. Data were obtained on a wide range of performance and internal and external characteristics of these businesses covering the period 1985-91. The report of this survey (SBRC 1992) provided the first comprehensive view of the UK SME sector since the report by Bolton (1971). A specific section dealing with innovation asked firms to report major innovations under a number of headings, as well as to report on R&D inputs and employment. The respondents to the original survey were then re-surveyed in 1993. The objective of the second survey was to examine financing constraints facing UK SMEs and evaluate the extent to which these affected performance, and did not include questions concerning innovation activity. This produced 1341 postal and fax responses.

A third survey of these firms, with a specific focus on the innovation process in the UK SME sector, was conducted in 1995. The results of this survey, based upon the European Commission Community Innovation Survey (CIS), provided substantially richer data on innovation than the 1991 survey. An important advantage of the third survey is that, unlike the first, it provides a measure of the novelty of an innovation. In addition to asking whether a firm had made product or process innovations, the 1995 survey enquired whether an innovation was simply new to the firm, or new to the firm's industry or new to all industries. It also included the full range of innovation input and output questions included in the CIS survey. The third survey obtained 1001 responses. Of these, 694 firms completed the full postal questionnaire and 307 returned shorter questionnaires by fax or telephone. Our analysis in this paper focuses mostly on the innovation output provided by these firms. However, our analysis of firm survival is dependent only on innovation responses in the 1991 survey and thus includes all of the original 2000 respondents. The precise questions asked in the 1991 and 1995 surveys are shown in the Appendix.

In both the second and third surveys, the CBR tracked down information on non-respondents from a wide variety of sources, thus providing information on firm failures in our sample. It was found that by 1995, 390 of the original sample of 2000 firms had failed or were moribund (e.g. in receivership) and a further 219 were acquired. A separate analysis of the characteristics of the 594 firms which were alive but did not respond has been carried out and shows no evidence for attrition bias which non-response may produce, at least in terms of size, industry, age or previous growth experience (see Bullock, Duncan and Wood 1996).

As the 694 postal responses to the 1995 survey provide the most detailed information on innovation patterns, we focus entirely on those firms in this section. A full discussion of the 1991 and 1995 results may be found in SBRC (1992) and Cosh and Hughes (1996) respectively. Table 1 shows a breakdown of the 694 firms, by size, age and sector. The breakdown of the SME sector by size is according to the standard European Commission definition, except that we have amalgamated the largest two size categories normally employed. Micro firms are defined as those employing between 1 and 9 employees, small firms as employing between 10 and 99 and medium sized firms as employing between 100 and 499 employees. The 694 firms are drawn roughly equally from the manufacturing and business service sectors and roughly equal proportions were started before and after 1980. Interestingly we find that, whilst business services have a higher proportion of micro firms, it is manufacturing which has the higher proportion of newer firms.

Whilst it is widely accepted that size and age influence innovative activity at the firm level (see, for example, Schumpeter 1934), several different explanations have been offered. These do not always imply the same type of relationship between innovation and either size or age. Larger, more established firms, it is argued, have greater financial resources to devote to research and development giving them a crucial advantage over smaller, newer firms in the area of innovation, particularly in innovation-intensive industries (Winter 1984). On the other hand, smaller and younger firms are said to possess greater organisational flexibility which implies better internal communication, closer relationships with suppliers and customers and less resistance to change from within the firm, thus conferring certain advantages on small younger firms in industries with rapid technological change (Mueller 1988; Scherer 1988). Clearly, the fact that the CBR database is restricted to SMEs limits our ability to contribute to this debate across the full size range. On the other hand it is unusual in enabling us to gain a detailed picture of variations in innovative activity within the SME sector based on a large sample of businesses in services as well as manufacturing.

The first three columns of Table 2a show a breakdown of innovation patterns by firm employment size within the CBR sample. The proportion of firms in each size group which report the introduction of innovations over the three years 1993-1995 increases steadily with increasing firm size. This is true both for product and process innovations and for innovations which are new to the firm, new to the firm's industry and new to all industries. Chi-square tests were used to test the significance of the differences in the proportion of firms in each size group reporting a particular type of innovation. In all cases, these differences were significant at the 5 percent level. A further disaggregation of the smallest size class (not reported in the table) reveals that firms with less than 5 employees are rarely innovative. Firms with over 5 employees account for 100% of novel innovations and 80% of all innovations from micro manufacturing firms. The remaining columns of Table 2a show the results of probit analyses of the relationships between different types of innovation and firm size. The first set of probits report the effect of size on innovativeness without controlling for age and industry. In the second set, we control for age and industry. In all types of innovation, innovativeness increases significantly with firm size. However, the greater the novelty of innovation, the smaller the impact of size on innovativeness. The probit analysis reveals that the impact of size on innovativeness is not sensitive to controls for age and industry.

The proportion of firms in each size group introducing product innovations is higher than that introducing process innovations, independent of the novelty of the innovation. In each size class, a much smaller proportion of firms which report product or process innovations new to their firm judged that those innovations were either new to their industry or to all industries.

It is interesting to compare these outcomes for our subject based survey with those arising from object based approaches. Our own calculations (see Table 2b) based on the SPRU database suggest that of the group of SMEs in the UK introducing "major technological innovations" in the period 1980-83, slightly fewer than half were firms with 100 or more employees and approximately 11 percent had fewer than 10 employees. The former is roughly the same as the proportion reported in similar work for the US (see Acs and Audretsch 1991, p 741). In contrast, the CBR innovation database suggests that just over 12% of SMEs with innovations new to all industries had 100 or more employees and over one third were micro firms. Both of these figures fall slightly when all SME innovators (both those with novel innovations and those with diffusion innovations) are considered, rather than focusing exclusively on novel innovators. The majority of both novel and diffusion innovators amongst manufacturing SMEs are small firms (those with 10 to 99 employees). It should be noted that Table 2b shows the proportion of innovating firms, not the proportion of innovations, within each size group. If, as is likely, the number of innovations per innovative firm increases with firm size, larger SMEs would account for a higher proportion of SME innovations than SME innovators.

Our results suggest that the object approach used in those studies underestimates the proportion of innovative SMEs which are small compared to the subject approach. Our subject approach implies that, despite the small proportion of micro SMEs likely to believe themselves to be pioneer innovators, their numerical significance in the economy as a whole means micro firms are likely to introduce more such innovations as well as diffusion innovations than medium sized firms. Also, the majority of innovators in the SME sector are likely to be small firms. It has to be recognised, however, that the object approach has the advantage of hindsight and identifies innovations which have in a sense made the grade. The subject approach is inevitably more contemporaneous and will include some innovations which in the course of time will be proved uncommercial. The subject approach is, therefore, more likely to reflect the seedbed role of the SME sector as a generator of novel innovations and experiments compared to the object approach.

Table 3 shows innovation patterns in the SME sector by firm age. The first two columns indicate the proportion of firms in different age groups which reported innovations. The differences in the proportion of firms reporting innovations between older and newer firms are small and not significant. The probit analyses using age as a continuous variable (reported in column 3) suggest a positive relationship. Column 5 shows however that this result reflects an aggregation bias arising from ignoring size and industry effects. Once these are allowed for, the probit analysis reveals that increasing age tends to reduce innovation and that this effect is statistically significant for product innovations new to the firm and for firms carrying out both product and process innovations new to all industries.

Table 4a shows in bold type the innovation patterns for the manufacturing and business service sectors separately. The proportion of firms introducing process innovations is virtually identical, though a marginally higher proportion of manufacturing process innovations were new to the firm's own industry than in business services. The proportion of manufacturing firms reporting the introduction of product innovations was higher than for business service firms, as was the proportion of these which were new to the firm's own industry or to all. There is a significant difference between manufacturing and the business service sectors in the proportion of firms reporting product innovations new to the firm. The proportion of firms reporting both product and process innovations new to the firm are also significantly higher in manufacturing. This may reflect an implicit bias against innovation reporting in service firms since the CIS definition of innovation emphasises technological aspects. Thus our 1991 survey which separately identified innovation in products or services, in production processes, in work practices or workforce organisation, and in administrative and office systems and which is not subject to this potential bias, shows similar major innovation rates in products (SBRC 1992).

Table 4a also shows innovation patterns across a more detailed breakdown of the manufacturing and business service sectors. Over 80 percent of electrical engineering firms reported product innovations; at least half of these reported that their innovations were new to their industry or all industries. Around 60 percent of chemical, mechanical engineering and metals firms reported product innovations and roughly 40 percent of these firms reported that their innovations were new to their industry or all industries. In the food, textile, timber and furniture, and paper industries, fewer than 15 percent of firms reported product innovations new to their own or all industries.

The chemical and metals industries are the most innovative in the area of process innovations. Over 50 percent of firms in these industries reported process innovations. Over 20 percent of chemicals firms reported process innovations new to their own industry or all industries, while the corresponding figure for metals was 15 percent. The combination of product and process innovations is most important in the chemicals industry with well over 50 percent of firms reporting the introduction of both novel product and novel process innovations.

Within the business services sector, the most innovative sector is technical and professional services. Nearly 60 percent of firms in this industry reported product innovations and one third of these were new to the firm's industry or all industries. Around 40 percent of advertising and management consultancy service and other business service firms reported product innovations and roughly 40 percent of these were new to the firm's own industry, all industries or both.

These results are consistent with those found by other studies (see Robson and Townsend 1984; Acs and Audretsch 1988, both of which use an 'object based' approach, and Archibugi and Pianta 1994). A common finding is that the most innovative manufacturing sectors are the engineering sectors including electrical engineering, chemicals, mechanical engineering and metals. This suggests that subjective evaluations may be as reliable as the object approach in mapping industry relativities.

Table 4b reports the results of probit analyses of the relationship between broad industrial sector and innovativeness. Only in the cases of product innovations new to the firm and product innovations new to the firm's own industry is sector a significant determinant. Manufacturing firms are more likely than business service firms to report such product innovations.

We conclude this section by noting that firm size and industry are important determinants of a firm's innovative activity. However, innovation should also be seen as part of a dynamic competitive process within these sectors. To explore the role of innovation further requires an insight into the causes and consequences of innovation within a competitive model. The analysis below focuses on the broadest definition of innovation, including both novel and diffusion innovations. This approach provides an important insight into the importance to firms of innovative activities in general and highlights the fact that the significant role of technological change is not limited to novel or "major" innovations.

3. Innovation and the Competitive Process

In a pioneering analysis, Downie (1958) proposed a model of the competitive process based upon the interaction between firm performance and innovation. He suggested that there were two, partially offsetting, forces of change at work within an industry in a market economy. The 'transfer mechanism' creates "a tendency for more efficient firms to grow ... at the expense of less efficient firms" (p 60). "If the transfer mechanism continued to be operated by an unchanged set of relative efficiencies the ultimate result could only be the concentration of the whole output of an industry in the hands of one, the most efficient, firm". Observing that we do not observe monopolies in all sectors, he argued that "there must therefore be some counter-force to the transfer mechanism" (pp 60-61). This he termed the 'innovation mechanism' and it results in a process "whereby relative efficiencies are changed" (62), through the uneven distribution of discoveries and application of new, more efficient production techniques.

Within this model, relatively slow growth or decline follows a decline in relative efficiency which in turn reflects a relative failure to innovate. In contrast with the array of innovative advantages usually attributed to efficient larger firms (e.g. Nelson and Winter 1978), Downie argued that slow growing (and thus less efficient) firms did not necessarily have a lower chance of success in innovation in the future. While acknowledging that less efficient slow growing firms are likely to have less financial resource to devote to innovative activity than more efficient, faster-growing firms, Downie argued that "it seems highly probable that the next advance in technique will be made by some other firm than the one which, by means of the last advance, made itself into the most efficient in the industry" (p 92). The reason for this is that more efficient firms will be less highly motivated to innovate than smaller less efficient firms. In addition to the pain of rethinking established habits and processes and the risk that innovation investment will be wasted, an efficient firm "will feel little immediate fear of being overtaken by others on a scale sufficient to threaten its position" (p 90). While a less efficient firm may suffer from less intimate knowledge of the currently most efficient techniques, it will be "free from the distorting influence of the pride of creation" (p 91). Another reason why less efficient firms may be the next to innovate is that technological advance may be faster than the replacement cycle. Most importantly, however, less efficient firms will be far more highly motivated to re-examine their existing methods and experiment with new ones. The transfer mechanism "threatens the inefficient firm with destruction, and I suggest that it is the efforts of such firms to avoid destruction which result in changes in the constellation of efficiencies" (p 62).

Downie's model sought to predict and explain changes in industrial concentration in terms of the interplay between the transfer and innovation mechanisms. The model did not take account of the possibility of takeovers through which larger firms, which grew as a result of their past innovation success, acquire small firms with the best current innovations. Such takeover activity might effect the functioning of the transfer mechanism in two markedly different ways. Such takeovers may enable large firms which grew as a result of past innovative success to stop the most innovative smaller firms from usurping their position, thereby obstructing the transfer mechanism. Alternatively, if smaller firms with innovative ideas lack the resources to market their ideas effectively, possibly as a result of imperfect capital markets, takeover may provide access to required resources and could enable them to grow relative to previous market leaders, thus to some extent promoting the transfer mechanism. In the latter, large firms play a second best role in filling the missing finance market left by imperfect capital markets. (see Hughes 1992; Cosh and Hughes 1994;

and Cosh and Hughes 1996). We return to this discussion in Section 5 when we analyse the impact of innovation on the probability of acquisition.

Relying on data for productivity as a proxy for a firm's innovativeness, Downie argued that there was empirical support for both the innovation and transfer mechanisms. In support of the innovation mechanism, Downie cited evidence from a sample of sixteen industries, in which productivity changes within firms in each industry were, in all cases, a negative function of the relative productivity at the start of the period. As evidence for the transfer mechanism, Downie maintained that the balance of evidence implied that the changes in relative firm sizes (measured by net output) within an industry were not random but were associated with relative efficiency, though he did acknowledge that changes in net output and productivity were only weakly correlated in his sixteen sample industries.

More recently, similar models to Downie's 'innovation mechanism' have been tested using innovation data generated by SPRU. Nickell and Nicolitsas (1995), for example, modelled the introduction of new technology on the change in market share, the change in profit per employee and change in the ratio of interest payments to cash flow. The Nickell and Nicolitsas results are consistent with the Downie hypothesis of an innovation mechanism since they observed a significant negative relationship between past change in profits per employee and the subsequent introduction of new technology.

There is also some evidence which implies the opposite, i.e. that current innovation performance is a positive function of past overall firm performance which implies that there is persistence in both innovativeness and overall performance. Blundell et al. (1993), for example, observed that within industries, firms with larger market shares were more innovative than others. As Geroski (1995) argues, however, this work suffers from the serious problem that it only employs a partial sample of the SPRU innovation data, ignoring many small firm innovations which dominate the database. The view that this may have affected the direction of the relationship that Blundell et al. observed is supported by the findings of Geroski and Pomroy (1990), who demonstrated that the innovation activity captured in the SPRU Innovation Data as a whole appears to have had a deconcentrating effect which is at odds with the notion of persistence in innovation and overall performance. In a second examination of the causality running from innovation to overall performance, using a partial sample of the SPRU innovation data, Geroski (1995) did not find any evidence of a significant relationship between innovation and either growth or profitability. This could be due to the fact that, as with Blundell et al. (1993), the sample excludes innovative small firms in the SPRU data.

In the following sections, we complement the above research on innovation in large firms by examining innovation and overall performance patterns in SMEs using the CBR panel database. In section 4, we examine evidence on the 'innovation mechanism', exploring data on the determinants of innovation in the 694 firms which responded to the most recent CBR survey. In section 5, we ask whether innovation helps firms avoid destruction and evaluate its link with the likelihood of acquisition. For this analysis, we use innovation data from the original CBR survey in 1991 and compare the subsequent survival of innovating and non-innovating firms.

4. The Determinants of Innovation

We examine evidence for an 'innovation mechanism' by testing for a positive impact of past relative decline on innovation using a simple probit model shown in Table 5. The dependent variable measures whether or not the firm introduced either a product or process innovation in the period 1992-95. We express this as a function of past innovation activity, past growth performance, the past competitive environment facing the firm, as well as size and age. We control for sectoral variation with industry dummies. Past innovation activity is measured by whether or not a firm introduced either a product or process innovation in the five years 1986-91.[2] Regarding past growth performance, in keeping with the view that decline in market share motivates innovation, we use as our measure the proportional change in employment over the period 1990-93 relative to the industry average.[3] Lower relative efficiency is expected to increase the innovative effort and hence increase the probability that a firm will introduce an innovation in the next period.[4] The effect of the competitive environment is measured by the number of serious competitors in 1991, the extent to which firms perceived increasing competition over the three years 1988-91 to be a significant limitation on their ability to meet their business objectives and a dummy for whether or not a firm reported that any of its competitors were overseas firms.

The results in Table 5 confirm the positive relationship between size and the propensity to innovate which we reported earlier. They do not, however, provide direct support for the proposition that poor growth performance relative to the industry average in the past provides a significant stimulus to innovate. The coefficient of employment growth in the period 1990-93 relative to the industry average, though signed as expected, is not significantly different from zero. Nor does increasing competition or the number of serious competitors significantly spur on innovation.

However, if a firm has overseas competitors it significantly increases the probability that it will innovate. Evaluated at sample medians, the results imply that firms which had overseas competitors in 1991 were more than 100 percent more likely than those which did not to have innovated in the three years 1992-95. This implies either that greater overseas competition encourages firms to innovate to maintain, or increase, their competitiveness or that firms that innovate are more likely to be in, or be moving into, markets characterised by international competition (Kitson and Wilkinson 1996). The model controls for industry effects, so one might argue that the former explanation is more appropriate, even though the 2-digit level industry dummies may be too aggregated to remove all industry effects. Perhaps more important is the fact that we are relating innovation to a lagged overseas competition variable. If the motivational hypothesis is correct, then it suggests that overseas and domestic competition are qualitatively different and that overseas competitors provide a greater competitive incentive to innovate than do domestic competitors.

Another significant determinant of current innovation performance is a track record in innovation. Evaluated at sample medians, our results imply that firms which introduced an innovation in the period 1986-91 were nearly 100% more likely than firms which did not to innovate in the three years 1992-95 (the estimated coefficient of innovation in the period 1896-91 is not significantly different from 1). There appears to be considerable persistence in innovative activity in this sample of firms. The probability of the introduction of either a product or process innovation in 1992-95 is greatly and significantly increased by the introduction of an innovation in the period 1986-91. This is not consistent with Downie's vision of past innovation failures attempting to catch up. The relative size of the coefficients suggests, however, that a track record in innovation is not as strong an influence on subsequent innovation activity as whether or not a firm has overseas competitors.

In Table 6, we examine a similar model, but this time for the probability of <u>planned future</u> innovation. Once again, the best predictors of future innovation are size, past innovative activity and whether or not a firm has overseas competitors. Poor employment growth performance as before does not appear to increase the probability of plans for future innovation. In contrast with Table 5, however, the relative coefficients in Table 6 imply that a track record in innovation is a stronger influence than the existence of overseas competition on a firm's plans to innovate in future. This may imply that while most current innovators intend to continue to innovate in future, those which do not have overseas competitors may be less likely to translate these intentions into actual innovations. This is also consistent with the motivational hypothesis.

In conclusion we find larger firms which have overseas competitors and have innovated are most likely to innovate in the next period. If their employment growth performance is below the industry average, there does not appear to be a significant change in their subsequent innovation activity, and the evidence for a powerful innovation mechanism is therefore weak. It might be argued that this reflects not a lack of desire to innovate as a way out of adversity, but a lack of resource to do so, especially financial resources in imperfect capital markets (Nickell and Nicolitsas 1995). A separate analysis by the present authors reveals that although financial constraints and the high cost of innovating are cited as the main barrier to innovation by CBR sample firms as a whole, there is no significant difference in the severity of these constraints as experienced by innovators and non-innovators respectively. Differences in access to market and technical information are more powerful discriminators between these two groups (Cosh, Hughes and Wood 1996).

5. The Consequences of Innovation for Survival, Acquisition and 'Failure'

In the previous section, we examined whether or not poor growth performance in the past motivates firms to innovate in the future. In this section, we ask whether or not the introduction of an innovation in the past increases the probability of firm survival, or in Downie's terms, enables a firm to "avoid destruction" (p 62), by failure or losing independence through acquisition. In other words, we are interested here in the question of whether or not the evidence indicates that innovation is indeed a good survival strategy.[5]

Table 7 shows the pattern of firm survival for innovating and non-innovating firms in both manufacturing and business services. The category 'failed or failing' includes all those firms which are confirmed as having already failed, are in receivership, have had winding up orders placed on them or are non-trading. Also included in this group are nineteen firms which could not be traced after an exhaustive process of checking telephone numbers and addresses, Companies House records, and a variety of electronic databases. In addition to analysing failed or failing firms, we consider firms which were acquired between 1991 and 1995.

Table 7 indicates a somewhat higher failure rate for business service than for manufacturing firms and vice versa for acquisition rates. It also shows that product and process innovations appear to have different effects on firm survival in both sectors. The introduction of product innovations reduces the likelihood of firm failure by a smaller margin than the introduction of a process innovation. And the introduction of a product innovation increases the probability that a firm will be taken over by a greater margin than a process innovation.

Table 8 shows the results of a probit analysis of the effects of product and process analysis on firm survival. The analysis indicates that process innovation significantly reduces the probability of firm failure. Product innovation is a significant positive determinant of the probability of a firm being acquired but has no impact on the probability of subsequent failure. Evaluated at sample medians, our results suggest that firms which introduced a process innovation in the five years 1986-91 were 22% less likely than those which did not to have failed by 1995 and those which introduced a product innovation in 1986-91 were 26% more likely than those which did not to have been acquired by 1995. Some caution is required in interpreting the latter result as it is sensitive to the approach taken to missing values for the innovation variables while the former is robust across different missing value schemes (see the Appendix). Older SMEs are significantly less likely to die or to be acquired and larger SMEs are significantly more likely to be the subject of a takeover. These results are broadly consistent with other studies of UK failure and survival (e.g. Cosh and Hughes 1994; Storey et al. 1987) except that the size effect on failure is somewhat weaker.

The lower probability of process innovators failing is entirely consistent with Downie's notion of a "transfer mechanism" whereby innovating firms outperform their non-innovating counterparts. Since survival appears not to be dependent on innovation in products, this implies that to increase survival chances, firms must innovate in the way in which products are produced and brought to the market.

It is less clear, however, what implications the higher probability of product innovators being acquired has in the context of the transfer mechanism. As noted above, Downie's model did not take account of the effect of takeovers on the functioning of the transfer mechanism. The truncation of our sample at 500 employees is particularly relevant here, since the mergers and acquisitions literature shows that the acquirers of innovative SMEs are likely to be those larger firms excluded from our sample. Does the loss of independence for product innovating firms in some sense imply failure or can it be considered as a form of success? There does not appear to be a simple answer to this question. While it is true that limited resources in an innovative small firm might leave it vulnerable to takeover by a larger firm which perceives the market potential of the innovation and posseses the skills and resources to market the product effectively, it is also true that some innovative small firms deliberately seek takeover (see for example ACOST 1990, Murray 1995). Whatever the precise motivational factors on the side of the small firm, the results are consistent with the idea that product innovation activity within the target firm is an important factor in the decision of the acquiring firm, and that acquisition may be an important exit route by which innovative entrepreneurs can capitalize on their past success by selling out the equity in their firm (Cosh and Hughes 1994).

6. Conclusions

The subject-based approach to investigating innovation patterns within the SME sector, while confirming some results obtained using the object-based approach, provides interesting new insights into the innovation process. The two approaches appear to produce similar innovation patterns across different industries, with the highest innovation rates in the engineering industries. However, the two approaches suggest rather different patterns of innovation across different sizes of SMEs. In particular, the subject-based approach adopted here suggests that although the probability of innovation and firm size are positively related, micro manufacturing firms account for a considerably higher proportion of manufacturing SME innovators than do medium sized firms, although the very smallest firms with less than 5 employees are significantly less likely to be innovators than those employing from 5 to 9 employees. The subject approach probably overstates the rate of 'successful' innovation compared to the object approach which is based more on hindsight. Our results are consistent with micro and small manufacturing firms playing an important "seed-bed" role in technological change and industry evolution.

Turning to the model of the competitive process, our probit results do not provide direct support for the notion of an "innovation mechanism" in which adversity fosters innovative activity. Poor growth performance does not appear to be a significant determinant of innovation activity. It should be noted, however, that one cannot conclude on the basis of this finding that such an "innovation mechanism" is not active, since we have not modelled as fully as we might the nature of the financial constraints facing firms in adversity, though what evidence we have does not suggest a difference in financial constraints between innovating and non-innovating firms. Nevertheless, our findings are consistent with the motivational hypothesis. Firms which have overseas competitors are significantly more likely to introduce innovations.

Our evidence provides clear support for a strong floor to the 'transfer mechanism' whereby innovating firms are less likely to fail than non-innovating firms. The introduction of process innovations significantly reduces the probability of firm failure. It appears that the introduction a product innovation does not help to reduce the probability of firm failure. However, firms which introduce product innovations are more likely to be acquired than non-innovators. If, as the results suggest, the decision of the acquiring firm is associated with product innovation activity within the target firm, with the acquiring firm seeing potential in the innovation to improve its own performance, then this is also consistent with a 'transfer mechanism'. Further analysis of the impact of innovation on export, turnover, employment and productivity growth will be the subject of future research.

Notes

1. The business service SMEs included are drawn from the following sectors: "management consulting and advertising" includes management, marketing, sales and technology consultants, personnel and human resources consultancies, public relations agencies, design consultancies, and market research and advertising agencies: "computing, professional and technical consulting" includes computer software and services, surveyors, architects, consulting engineers, and other professional and technical services: "other business services" comprise a small group of miscellaneous business services including contract cleaning (see Bryson, Keeble and Wood, 1996).

2. The parameter estimates shown in Table 5 use some imputed data for innovation activity in the period 1986-91. For details of the imputations and an analysis of the sensitivity of the parameter estimates to alternative imputation schemes, see the Appendix where we show that the significance of the reported results is not generally sensitive to the imputation method chosen.

3. The reason for using changes in employment rather than in turnover as an indicator of growth was the smaller number of missing values for employment. Despite the high level of correlation between turnover and employment in our data, the use of employment data might introduce an interpretation problem as a decline in employment may be associated with a loss of market share, rising productivity growth or a combination of both.

4. It could be argued that if a firm is motivated to introduce an innovation by relatively poor growth performance in the past, the amount of effort that it can expend towards this end will be

constrained by its financial position. To measure the strength of this effect, we included profit margin as an explanatory variable. It was in all cases insignificant. There are a significant minority of firms which did not provide data on profits so including profitability meant that a number of cases had to be excluded from the model. Given the missing values and the insignificance of profit margin, it was excluded from the model.

5. Clearly, the impact of innovation on productivity, export, turnover and employment growth performance is also of direct relevance to the concept of a "transfer mechanim". A preliminary analysis of the relationship between innovation and employment growth performance can be found in Cosh, Hughes and Wood (1996), who found a significant positive relationship between innovation and employment growth. A more detailed analysis of these relationships will be the subject of future work.

TABLES

Table 1: Characteristics of 694 SMEs in the 1995 postal innovation survey[a]

Number (%) of firms in each category

	Micro	Small	Medium	**All**	Older	Newer
No. employees in 1990/ Year firm started	1-9	10-99	100-499		Pre-1980	Post-1980
	No (%)	No (%)	No (%)	No	No (%)	No (%)
All firms	**138 (23)**	**344 (58)**	**114 (19)**	**694**	**295 (44)**	**378 (56)**
Metals	2	20	8	**34**	12	21
Chemicals	4	16	7	**33**	11	22
Mechanical engineering	14	64	15	**108**	33	71
Electrical engineering	7	23	8	**43**	20	21
Food processing	1	8	5	**15**	3	12
Textiles, clothing, footwear	2	23	8	**36**	7	28
Timber and furniture	5	16	3	**29**	8	20
Paper and pulp	13	27	7	**53**	20	33
All manufacturing	**48 (16)**	**197 (64)**	**61 (20)**	**351**	**114 (33)**	**228 (67)**
Management consulting & advertising	44	76	29	**178**	95	80
Technical and professional consulting	27	49	14	**110**	58	46
Other business services	16	20	9	**49**	27	19
All business services	**90 (31)**	**147 (51)**	**53 (18)**	**343**	**181 (55)**	**150 (45)**

(a) In some cases, the sub-totals do not add up to the total shown. In the case of different firm size categories, this is because some firms from the original sample had outgrown their SME status and had more than 500 employees. In addition, some firms did not provide information on the number of employees. In the case of older and newer firms, some firms did not report the year in which they were started. For companies which fell in this category we were able to establish age by independent checks at Companies House; for the small number of our sample not reporting age and which were also partnerships or sole proprietorships this check was not possible and so it was not feasible to calculate their age.

Table 2a: Innovation patterns by firm size

Firm size group	Micro	Small	Medium	Prob (innov)= f(log size)[a]		Prob (innov)= f(log size)[b]	
No. of employees	1-9	10-99	100-499	β	T value	β	T value
% Firms in each size group reporting:							
Product innovations:							
New to firm	34**	54**	70**	0.24	6.25**	0.27	6.32**
New to own industry	14**	21**	32**	0.15	3.67**	0.19	4.05**
New to all industries	10**	14**	24**	0.14	3.07**	0.17	3.36**
Process innovations:							
New to firm	27**	48**	62**	0.26	6.71**	0.28	6.66**
New to own industry	7**	9**	25**	0.23	4.57**	0.25	4.54**
New to all industries	6**	6**	13**	0.15	2.59**	0.16	2.63**
Both product & process innovations:							
New to firm	10**	32**	52**	0.35	8.10**	0.36	7.95**
New to all industries	3**	3**	9**	0.14	2.14**	0.18	2.52**

(a) Probits include no dummies.

(b) Probits include logarithm of age, and industry dummies (either for the industries shown in Table 1 or, in cases of non-convergence, simply for manufacturing/services).

Note: Chi^2 tests were used to examine whether the proportion of firms which reported a particular type of innovation was significantly different across the different firm size groups.

** Significant at the 5 percent level (either Chi^2 test or t statistic). * Significant at the 10 percent level.

Table 2b A comparison of innovation patterns by firm size[a]

Firm size group	Micro	Small	Medium	All SMEs	Number of firms
No. of employees	1-9	10-99	100-499	1-499	
CBR SME Innovation Survey 1995					
% Firms in each size group reporting:					
Either product or process innovations:					
New to firm	50.0**	70.6**	86.9**	**70.6**	**216**
New to all industries	16.7**	16.8**	31.1**	**19.6**	**60**
% UK manufacturing SMEs in each size group					
All UK manufacturing SMEs excluding those with less than 5 employees[b]	37.4	55.7	6.9	**100**	**72430**
All innovative UK manufacturing SMEs[c]	29.2	61.4	9.4	**100**	**46366**
All UK manufacturing SMEs introducing novel innovations[d]	**35.2**	**52.7**	**12.1**	**100**	**12856**
SPRU Innovation Survey 1983					
No. of SMEs in each size group introducing a "major innovation" in the period 1980-83	13	50	60	**123**	**123**
% of all SMEs introducing a "major innovation" in the period 1980-83 by size group	**10.6**	**40.7**	**48.8**	**100**	**123**

Note: Chi^2 tests were used to examine whether the proportion of firms which reported a particular type of innovation was significantly different across the different firm size groups.

(a) Only manufacturing firms are included in this table owing to availability of employment size class data for UK SME sector.

(b) Taken from the DTI (1996). Firm data refer to 1994. The reason for excluding firms with fewer than five employees is that amongst micro firms in the 1995 survey, 100% of those with novel innovations and 80% of those with any type of innovation had five or more employees.

(c) Assumes that firms in each category introduce product or process innovations with the same likelihood as the corresponding firms in the CBR innovation survey.

(d) Assumes that firms in each category introduce novel innovations with the same likelihood as the corresponding firms in the CBR innovation survey.

Table 3: Innovation patterns by firm age

Age group	Older	Newer	Prob (innov)= f (log age)[a]		Prob (innov)= f (log age)[b]	
Year firm began trading	Pre-1980	1980+	β	T value	β	T value
% Firms in each size group reporting:						
Product innovations:						
New to firm	52	54	-0.00	0.07	-0.18	2.48**
New to own industry	20	20	0.04	0.56	-0.10	1.27
New to all industries	14	14	0.02	0.31	-0.11	1.19
Process innovations:						
New to firm	49	42	0.12	1.99**	-0.02	0.34
New to own industry	11	11	0.27	0.50	-0.13	1.37
New to all industries	7	6	-0.00	0.01	-0.15	1.41
Both product & process innovations:						
New to firm	34	28	0.14	2.18**	-0.07	1.00
New to all industries	4	4	-0.11	0.94	-0.25	1.99**

(a) Probits include no dummies.

(b) Probits include logarithm of size, and industry dummies (either for the industries shown in Table 1 or, in cases of non-convergence, simply for manufacturing/business services).

Note: Chi^2 tests were used to examine whether the proportion of firms which reported a particular type of innovation was significantly different across the different firm age groups.

** Significant at the 5 percent level (either Chi^2 or t statistic). * Significant at the 10 percent level.

Table 4a: Innovation patterns by sector and industry

Sector	Metals	Chemi	Mechanic engin.	Electri engin.	Food	Textile & clothing	Timber & furnit	Paper & pulp	**All manufact**	Manage consulting	Technical consulting	Other bus. services	**All business services**
Number of firms	34	33	108	43	15	36	29	53	**351**	178	110	49	**343**
% Firms in each sector reporting:													
Product innovations:													
New to firm	62**	73**	61**	84**	60**	39**	48**	40**	**58****	40**	59**	39**	**46****
New to own industry	24**	30**	26**	40**	13**	14**	10**	13**	**23**	15**	20**	18**	**17**
New to all industries	18**	27**	17**	28**	7**	6**	3**	9**	**15**	11**	15**	12**	**13**
Process innovations:													
New to firm	65	61	42	49	33	42	38	42	**46**	47	46	37	**46**
New to own industry	15	21	14	12	13	11	14	2	**12**	8	10	10	**9**
New to all industries	12**	18**	7**	5**	7**	8**	3**	2**	**7**	6**	6**	10**	**6**
Both product & process innovation:													
New to firm	44**	55**	32**	44**	33**	17**	24**	30**	**35****	25**	35**	20**	**27****
New to all industries	6**	12**	4**	5**	7**	0**	0**	0**	**4**	3**	5**	6**	**4**

Note: Chi^2 tests were used to examine whether the proportion of firms which reported a particular type of innovation was significantly different across the different industries and sectors.

** Significant at the 5 percent level * Significant at the 10 percent level.

Table 4b: Probit analysis of innovation patterns by sector

Sector	Prob (innovating)= f(manufacturing)[a] β	Prob (innovating)= f(manufacturing)[a] t value	Prob (innovating)= f(manufacturing)[b] β	Prob (innovating)= f(manufacturing)[b] t value
% Firms in each sector reporting:				
Product innovations:				
New to firm	0.31	3.17**	0.30	2.98**
New to own industry	0.18	1.64	0.19	1.68*
New to all industries	0.13	1.11	0.15	1.17
Process innovations:				
New to firm	0.02	0.23	-0.07	0.67
New to own industry	0.15	1.20	0.10	0.70
New to all industries	0.03	0.22	-0.00	0.02
Both product & process innovation:				
New to firm	0.20	2.02**	0.13	1.16
New to all industries	-0.08	0.47	-0.08	0.44

(a) Probits include no dummies.
(b) Probits include logarithm of age and logarithm of size.

** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 5: The impact of past performance and environment on subsequent innovation activity

	Probability (product or process innovation 1992-95)	
	β	t value
Intercept	-0.042	(0.05)
Either product or process innovation 1986-91[a]	0.981	(4.22)**
Employment growth 1990-93 (cf. industry average)	-0.006	(0.15)
Log of number of serious competitors in 1991	-0.199	(1.64)
Increasing competition 1987-90[b]	-0.108	(1.22)
Dummy for overseas competition in 1991	1.119	(3.70)**
Log (employment size)	0.357	(3.25)**
Log (age)	-0.218	(1.22)
N	468	
Chi^2 goodness of fit test	(P = 0.451)	

(a) Roughly one third of respondents to the 1991 survey did not answer one or more of the questions regarding their innovation activity in the period 1986-91. Missing values were classified using multiple imputation techniques following (Little and Rubin 1990). For an analysis of the sensitivity of the parameter estimates to alternative imputation schemes, see the Appendix.

(b) Respondents were asked to score the importance of various factors, one of which was 'increasing competition', as a limitation on their ability to meet their business objectives. A score of 1 denoted that a factor was an 'insignificant' limitation on their ability to meet their business objectives while a score of 4 denoted 'very significant' and 5 'crucial'.

Note: probit include industry dummies.

** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 6: The impact of current performance and environment on plans to innovate in future

	Probability (planned innovation 1995-97)	
	β	t value
Intercept	-2.413	(2.90)**
Either product or process innovation 1992-95	2.674	(9.26)**
Employment growth 1990-95 (cf. industry average)	0.133	(0.80)
Log of number of serious competitors in 1995	0.153	(1.31)
Increasing competition 1992-95[a]	-0.096	(0.79)
Dummy for overseas competition in 1995	1.273	(3.75)**
Log (size)	0.200	(2.03)**
Log (age)	0.009	(0.04)
N	483	
Chi^2 goodness of fit test	(P = 0.13)	

(a) Respondents were asked to score the importance of various factors, one of which was 'increasing competition', as a limitation on their ability to meet their business objectives. A score of 1 denoted that a factor was an 'insignificant' limitation on their ability to meet their business objectives while a score of 4 denoted 'very significant' and 5 'crucial'.
Note: probit include industry dummies.
** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 7: Consequences of innovation activity for firm survival

	All firms	Status of firm in 1995 (%)					
	1991	Failed or failing		Acquired/merged		Alive & independent	
Number of firms[a]							
Manufacturing	**1050**	171	(16.3%)	129	(12.3%)	750	(71.4%)
Business services	**930**	219	(23.5%)	90	(9.7%)	621	(66.8%)
Total	**1980**	390	(19.7%)	219	(11.1%)	1371	(69.2%)
% Reporting product innovation 1986-91[b]							
Manufacturing		49		70[pq]		55	
Business services		50		69[pq]		55	
Total		50		69[pq]		55	
% Reporting process innovation 1986-91[b]							
Manufacturing		43		69[pq]		57[p]	
Business services		25		38		33	
Total		33		56[pq]		46[p]	

(a) Does not add up to 2028 owing to missing industry data for 1991, and exclusion of firms which were acquired by 1991 or which employed more than 500 employees in 1991. Roughly one third of respondents to the 1991 survey did not answer one or more of the questions regarding their innovation activity in the period 1986-91. The figues in the table correspond with case 3 in Table A1 in the Appendix.

(b) Each cell represents the proportion of firms with a particular status which reported a product or process innovation in the period 1986-91. Roughly one third of respondents to the 1991 survey did not answer one or more of the questions regarding their innovation activity in the period 1986-91. Missing values were classified using multiple imputation techniques following (Little and Rubin 1990). For an analysis of the sensitivity of the parameter estimates to alternative imputation schemes, see the Appendix.

Note: Bonferroni one way ANOVA comparisons were used to test whether differences in the proportion of firms which reported a particular type of innovation were significant at the 5 percent level.

(p) Proportion of innovative firms significantly higher than for 'failed or failing' firms.

(q) Proportion of innovative firms significantly higher than for 'alive and independent' firms.

Table 8: Probit results of survival on product and process innovation

	Probability (failure 1991-95)[a]		Probability (takeover 1991-95)[b]	
	β	t value	β	t value
Intercept	-0.147	(0.59)	-1.205	(2.97)**
Product innovation 1986-91[c]	0.007	(0.08)	0.256	(2.48)**
Process innovation 1986-91[c]	-0.221	(2.53)**	-0.010	(0.09)
Log (size)	-0.008	(0.25)	0.285	(7.76)**
Log (age)	-0.212	(4.00)**	-0.331	(3.51)**
N[d]	1628		1481	
Chi^2 goodness of fit test	(P = 0.36)		(P = 0.36)	

(a) The sample for this probit includes "alive and independent" and "failed or failing" firms but excludes all acquired firms.
(b) The sample for this probit includes "alive and independent" firms and acquired firms but excludes "failed or failing" firms.
(c) Roughly one third of respondents to the 1991 survey did not answer one or more of the questions regarding their innovation activity in the period 1986-91. Missing values were classified using multiple imputation techniques following (Little and Rubin 1990). For an analysis of the sensitivity of the parameter estimates to alternative imputation schemes, see the Appendix.
(d) Not all cases could be included owing to missing age or employment data.

Note: Probits include industry dummies.

** Significant at the 5 percent level. * Significant at the 10 percent level.

Appendix: The questionnaire approach to innovation and the problem of missing values

Innovation questions in the 1995 Survey

*In this section we would like you to tell us about your innovative activity. We are interested in innovation in products and processes which are **new to your firm.***

*In answering the questions in this section, please count innovation as occurring when a new or changed product is introduced to the market (product innovation) or when a new or significantly improved production method is used commercially (process innovation), and when **changes** in knowledge or skills, routines, competence, equipment, or engineering practices are required to make the new product or to introduce the new process.*

*Please do **not** count as product innovation, changes which are purely aesthetic (such as changes in colour or decoration), or which simply involve product differentiation (that is minor design or presentation changes which differentiate the product while leaving it technically unchanged in construction or performance).*

B1 Has your firm introduced any innovations in products (goods or services) or processes during the last three years which were new to your firm? *(Please tick only **one** box in **each** row)*

	Yes	No
Products		
Processes		

If you ticked No for <u>both</u> products <u>and</u> processes please skip B2-B6 and move onto question B7.

B2 If you introduced a product innovation, was it, to the best of your knowledge, already in use in other firms either in (a) your industry or (b) other industries? If you made more than one product innovation please answer with respect to your most important product innovation. *(Please tick only **one** box in **each** row)*

Product Innovation	Yes	No	Don't Know
(a) in use in your industry			
(b) in use in other industries			

B3 If you introduced a process innovation was it, to the best of your knowledge, already in use in other firms either in (a) your industry or (b) other industries? If you made more than one process innovation please answer with respect to your most important process innovation. *(Please tick only **one** box in **each** row)*

Process Innovation	Yes	No	Don't Know
(a) in use in your industry			
(b) in use in other industries			

Innovation question in the 1991 Survey

F1. Has your firm been successful in introducing any major innovations during the **last 5 years**? tick as appropriate

	Yes	No
In products or services		
In production processes		
In work practices, or workforce organisation		
In supply, storage or distribution systems		
In administration and office systems		

If YES, please give brief details

The missing value problem for innovation data from the 1991 survey

Of the 2028 responses to the 1991 survey, 555 (27.4%) firms did not respond to the question regarding the introduction of product innovations and 769 (37.9%) did not respond to the process innovation question. A similar problem arose in the 1995 survey with question B1, but it was possible in this survey to deduce answers for most cases by referring to responses to questions B2 and B3. The resulting proportion of missing values for the innovation questions in the 1995 survey was only slightly above 1 percent.

In dealing with the missing values for the innovation questions in the 1991 survey, we adopt the approach of Little and Rubin (1990) who recommend multiple imputation. This technique involves considering the possible missing data mechanism in both data collection and data analysis and matching alternative imputation schemes to the likely missing data mechanisms. This results in multiple imputations for the missing values which can be used to reflect the uncertainty due to nonresponse.

There are various possible explanations for the missing data problem in the 1991 survey. The following is a list of possible missing data mechanisms for the innovation questions in the 1991 survey along with an appropriate approach for dealing with missing values:

1. There is no identifiable missing data mechanism and missing value cases are all excluded.
2. All missing values both for product and process innovation represent cases of non-innovation.
3. The missing values are the result of uncertainty due to insufficient preamble in the 1991 survey explaining precisely what was meant by innovation and what kind of product/process improvements were not considered to represent an innovation. Missing values are classified as innovators or non-innovators using discriminant analysis. The probability of being assigned to either group is 50%. In practice, this results in the majority of missing value cases both for product and process innovation being classified as non-innovators.
4. As in 3 above, but missing values are classified as innovators or non-innovators using discriminant analysis in which the probability of being assigned to either group is not 50% but according to the probability of actual respondents responding yes or no to a particular kind of innovation.
5. The missing values for process innovation are, in part, special because the wider set of options in the 1991 survey compared with the 1995 survey (see the questionnaires above) meant that many firms

(particularly service firms) which would have answered yes to process innovation in 1991 had the question been phrased in the way it was in 1995, actually made no response to process innovation. For example, a respondent from a service firm in which a new computing system had been installed read through all the options and seeing administration and office systems, decided that was more appropriate than production processes and so replied yes to the former and left the latter blank. Missing values are classified according to the following scheme. Firstly, only those firms which did not respond to the question on innovation with regard to any of the categories of production processes, work practices, or workforce organisation, supply, storage or distribution systems, administration and office systems were assigned a missing value for process innovation. Of the remaining cases, all firms replying in the affirmative to any of the above categories were entered as process innovators and all others as non-innovators. Secondly, for the remaining missing values, the cases were classified as innovators or non-innovators using discriminant analysis in which the probability of being assigned to either group is 50%.

6. As above, but nonrespondents are classified as innovators or non-innovators using discriminant analysis in which the probability of being assigned to a group is not 50% but according to the probability of actual respondents reporting an innovation.

All the analysis in this paper which uses the data for innovation in the five years 1986-91 is repeated in Table A1 using these six alternative approaches to dealing with missing values. The estimates shown in bold are those shown in the analysis above, as these are considered to represent the most plausible explanation and provide the least results. The table indicates little variation in the estimates under the different assumptions. Only in the models for the probability of takeover does the significance of the estimates for innovation in the period 1986-91 differ across the six alternative approaches, with the estimate for product innovation being significant at the 5% level for three alternatives, at the 10% level under one alternative and insignificant in the others.

Table A1: The impact of missing value classification on equation estimates

Run number	1		2		3		4		5		6	
	The allocation of missing values for the innovation variables 1986-91											
	x	y	x	y	x	y	x	y	x	y	x	y
Product innovation 1986-91	896	0	896	0	**1125**	**229**	1222	326	1125	229	1222	326
No product innovation 1986-91	577	0	1132	555	**903**	**326**	806	229	903	326	806	229
Totals	**1473**	**0**	**2028**	**555**	**2028**	**555**	**2028**	**555**	**2028**	**555**	**2028**	**555**
Process innovation 1986-91	622	0	622	0	**900**	**278**	725	103	1370	748	1502	880
No process innovation 1986-91	637	0	1406	769	**1128**	**491**	1303	666	658	21	526	-111[+]
Totals	**1259**	**0**	**2028**	**769**	**2028**	**769**	**2028**	**769**	**2028**	**769**	**2028**	**769**

	b1	b2	**b3**	b4	b5	b6	Mean	Standard deviation
	Parameter estimates under alternative assumptions							
	Probability (product or process innovation 1992-95)							
intercept	0.081	-0.016	**-0.042**	-0.071	-0.105	-0.147	-0.050	0.079
either product or process innovation 1986-91[a]	0.855**	0.983**	**0.981****	0.984**	1.03**	1.054**	0.981	0.069
employment growth 1990-93 (cf. industry ave)	0.057	-0.008	**-0.006**	-0.006	-0.003	-0.004	0.000	0.026
log of number of serious competitors in 91	-0.239	-0.209*	**-0.199**	-0.201	-0.196	-0.201*	-0.208	0.016
increasing competition 1987-90[b]	-0.192	-0.112	**-0.108**	-0.106	-0.117	-0.105	-0.123	0.034
dummy for overseas competition	1.354**	1.150**	**1.119****	1.142**	1.237**	1.242**	1.207	0.088
log (employment size)	0.436**	0.368**	**0.357****	0.353**	0.355**	0.363**	0.372	0.032
log (age)	-0.114	-0.210	**-0.218**	-0.206	-0.246	-0.254	-0.208	0.050
N	269	468	**468**	468	468	468		
Chi^2 goodness of fit test	0.59	0.45	0.45	0.44	0.51	0.51		
	Probability (failure 1991-95)							
intercept	0.186	-0.152	**-0.147**	-0.129	-0.085	-0.051	-0.063	0.128
product innovation 1986-91	0.144	0.031	**0.007**	-0.026	0.023	0.051	0.038	0.058
process innovation 1986-91	-0.478**	-0.375**	**-0.221****	-0.205**	-0.252**	-0.323**	0.000	0.105
log (employment size)	-0.053	-0.012	**-0.008**	-0.007	0.000	-0.003	-0.014	0.020
log (age)	-0.149**	-0.202**	**-0.212****	-0.213**	-0.213**	-0.210**	-0.200	0.025
N	890	1628	1628	1628	1628	1628		
Chi^2 goodness of fit test	0.41	0.34	0.36	0.36	0.33	0.27		
	Probability (takeover 1991-95)							
intercept	-0.829	-1.169**	**-1.205****	-1.184**	-1.203**	-1.199**	-1.132	0.149
product innovation 1986-91	0.061	0.240**	**0.256****	0.175*	0.271**	0.151	0.192	0.080
process innovation 1986-91	0.051	-0.135	**-0.010**	0.006	-0.052	0.062	0.000	0.073
log (employment size)	0.330**	0.292**	**0.285****	0.289**	0.288**	0.287**	0.295	0.017
log (age)	-0.454**	-0.327**	**-0.331****	-0.333**	-0.330**	-0.335**	-0.352	0.050
N	811	1482	1482	1482	1482	1482		
Chi^2 goodness of fit test	0.09	0.34	0.36	0.32	0.37	0.31		

(x) All cases in the innovation variables 1986-91 including those which were assigned values
(y) Numbers of cases which were assigned values
Note: probits include industry dummies.
** Significant at the 5 percent level. * Significant at the 10 percent level.

[+] The reason why this number is negative is that several firms which reported that they had not introduced a process innovation in the 5 years 1986-91, reported that they had introduced innovations in work practices, or workforce organisation, supply, storage and distribution systems, or in administration and office systems.

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