A DIFFERENT PATH TO GROWTH? SERVICE INNOVATION AND PERFORMANCE AMONGST UK MANUFACTURERS

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Abstract

Introducing and innovating services is advocated as a means by which manufacturing firms in advanced economies can retain or enhance their competitiveness. But little is known about how manufacturers innovate services, nor about the impact of service innovation on manufacturers' performance. Using two consecutive waves of the UK Innovation Survey, this paper first examines how manufacturers innovate services, comparing this with how they innovate goods (i.e., material products) and production processes. We find that manufacturers tend to innovate services differently: R&D is found to be unimportant, whilst investments in marketing and training are found to be related to service innovation. The paper then examines the impact of service innovation on performance, in terms of innovative sales per employee and total sales per employee. We find that service innovation does not increase innovative sales but is associated with higher total sales per employee.

Keywords: Service Innovation, Servitization, Innovation Survey, Multivariate Probit, Multinomial Logit.

JEL codes: O30, O32, O40

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1. Introduction

In an era of globalisation and open markets, where high quality products can be produced at substantially lower costs in China and other emerging economies, manufacturers in high cost locations such as Western Europe, Japan and the US, have, in recent years, been urged to 'go downstream' (Wise and Baumgartner, 1999) or to 'move up the value chain' (Porter and Ketels, 2003) in order to retain or enhance their competitiveness. An important element within this is a shift from a focus on 'making things', that is the manufacture of material goods, to the provision of services, and indeed combinations or bundles of goods and services, sometimes in the form of 'integrated solutions' (Neely, 2008; Davies, 2003). Advocates of these 'servitization' strategies argue that they enable manufacturers to get closer to their customers, enhancing understanding of users' needs, strengthening relationships and increasing customer loyalty (Vandemerwe and Rada, 1988). The provision of services, and goods-service combinations, which are harder than stand-alone goods to imitate, also raises barriers to entry and increases customers' switching costs, thereby reducing competition, especially corrosive price based competition. Furthermore, providing services allows manufacturers to capitalise on the installed base of previously produced equipment that requires maintenance and operational support. Providing product support and services is also associated with steadier income flows, especially with high priced goods, which means businesses are less vulnerable to economic cycles outside of their direct control (Olivia and Kallenberg, 2003; Malleret, 2006).

Despite being advocated for over twenty years, little is known about the extent to which manufacturing firms provide and innovate services. Drawing on a survey of UK manufacturers, Baines et al find that the vast majority (c.95%) of manufacturers provide services, although most commonly they provide basic, or 'protective services', such as training, delivery, spares, repairs and helpdesks. By contrast, relatively few firms (c.25%) provide higher level, 'proactive services', such as systems integration, condition monitoring, and preventive maintenance, which Baines et al see as being oriented to winning new business. Meanwhile, a recent survey of 300 UK manufacturers by the Engineering Employers Federation found that on average these derived 12% of their income from services (EEF, 2009). Little is also known however about how manufacturers innovate services, and whether innovating services is associated with different behaviours from those associated with innovating material goods or production processes. In this paper we report the extent of service innovation amongst manufacturing firms in the UK, and examine how manufacturers are developing innovative services by comparing the behaviours associated with service innovation with those associated with goods and production process innovation. We also examine the impact of different types of innovation, and their combinations, on firm performance. Performance is measured in terms of innovative sales per employee, and total sales per employee. We are particularly interested in whether firms that introduced innovative services outperform those that did not; in other words, does innovating services enhance performance?

The analysis in this paper is based on a sample of 2,272 manufacturing firms that responded to both the UK Innovation Survey of 2005 and that of 2007 (hereafter UKIS-2005 and UKIS-2007 respectively). These surveys are the UK versions of the 4^{th} and 5^{th} Community Innovation Surveys (CIS-4 and CIS-5) that are now carried out in most European and other countries according to a common framework. The empirical analysis follows three steps. First, we use a multivariate probit to analyse factors associated with the introduction of goods, service and process innovations. This method allows for possible correlations between the different behaviours under investigation. Then we use a multinomial logit model which allows us to examine the difference between firms that innovated services and those that did not (and, in effect, to control for other innovation behaviours related to goods and processes). Finally, we examine the impact of different types of innovation on firm performance, measured in terms of innovative sales and total sales per employee.

The paper is organised as follows: Section 2 reviews the literature on the main objectives and determinants of innovation, focusing especially on service innovation, and differences between goods, processes and service innovation. Section 3 describes the data and presents the variables used in the analysis. Section 4 discusses the empirical method and presents the results, whilst Section 5 discusses the findings, outlines the limitations, and concludes the paper.

2. Literature Review

The Traditional Dichotomy: Product and Process Innovations

Although Schumpeter identified several types of innovation, the empirical literature is largely framed around a dichotomy between product and process innovation (for a recent review, see Damanpour and Aravind, 2006). Of the two, process innovation has received less attention, but is typically associated with increasing efficiency by reducing unit costs, reducing waste, improving consistency of production, and/or achieving compliance with regulations and standards, such as those pertaining to health and safety or pollution emissions

(Becheikh et al, 2006; Pisano, 1997; Reichstein and Salter, 2006). Although widespread, process innovation is thought to be particularly important amongst large, scale intensive businesses (Pavitt, 1984; Pavitt et al, 1987), and those in mature industries, especially where products conform to a dominant design (Utterback, 1994; Suarez and Utterback, 1995) or architecture. Process innovation typically involves changes to production operations, including task specifications, work and information flow mechanisms, and the equipment used in production (Tushman and Anderson, 1992:313); it is often, even typically, associated with investments in advanced machinery and equipment. Whilst these investments may be associated with Taylorist and Fordist automation and deskilling (Braverman, 1974), process innovations can also be associated with 'up-skilling', coupling investments in advanced equipment with investments in human capital, so that labour and equipment can be combined more effectively (Prais, 1995; Tether et al., 2005). Process innovation has also been associated with maintaining close relations with suppliers of equipment, especially when leading edge rather than older, standardised equipment is utilised. Here, process innovators may act as the 'lead users' of innovative equipment developed by others; they are the users in user-producer inter-relations (von Hippel, 1988).

Product innovation, the introduction of new and significantly changed products, has attracted much more attention than its less glamorous cousin. Indeed, the *International Journal of Product Innovation Management* is dedicated to the study of product innovation and its management. Product innovation is usually undertaken in order to expand the market served by the business and/or to enhance the attractiveness of what is offered to customers, such that they are prepared to pay higher prices, or to pay for products with higher margins. Product innovation, particularly in the form of technologically advanced, new and improved goods, is generally associated with investments in research and development (R&D) (Pavitt, 1984) and the employment of highly skilled scientists and engineers. It is also associated with investments in marketing and, less frequently, with investments in design (Marsilli and Salter, 2006; Tether, 2009). Whereas process innovation is associated with learning from and with suppliers, product innovation is associated with learning from and with customers, including lead users (von Hippel, 1988). Firms of all sizes engage in product innovation (Cohen, 1995; Tether, 1998), and the effect of size on product innovation is typically weaker than with process innovation. New firms are also an important source of product innovation (Acs and Audretsch, 1988; Shane, 2001). The appropriation regime within which the firm operates should also influence the extent to which they engage in product innovation, and indeed the incremental or radical nature of their product innovation activities (Teece, 1986). Where the appropriation regime is tight, and patents and other forms of intellectual property protection are effective, incentives for firms to introduce novel products are increased. By contrast, where the appropriation regime is weak, with formal intellectual property rights offering little or no protection against copying, the extent of radical product innovation is likely to be lower, with a greater orientation towards incremental innovation.

For our purpose, the traditional dichotomy between product and process innovation is problematic. For product innovation conflates the development and introduction of new and improved goods (i.e., material products, which are usually exchanged in transactions), with the development and introduction of new and improved services, which are often relational. Services are acts or performances (Gallouj and Weinstein, 1997), and as such tend to be processes rather than objects or things. Due to their intangible or immaterial nature, and because they are performed for or with the client, 'service products' typically share some features with goods and other features with processes; by extension, service innovation shares some features with goods innovation and some with process innovation. Like goods innovation (and unlike production process innovation), innovating services tends to have an external orientation – with a focus on addressing customer needs, rather than an internal focus on the means of production. This suggests that more might be learnt about product innovation by disaggregating goods and service innovations into two distinct categories and examining these separately.

A second problem with the traditional dichotomy is that it implies product and process innovation are disconnected and separate, and that firms innovate each independent of the other. In other words, product and process innovation are considered, implicitly at least, to be at most loosely coupled, rather than tightly coupled or inter-dependent. This may be an oversimplification; Pisano (1997), Martinez-Ros (2000), and Damanpour and Gopalakrishnan's (2001) have all found inter-relations between product and process innovation, and Reichstein and Salter (2006) conclude from their study that product and process innovations 'should be seen as "brothers" rather than "distant cousins"' (Reichstein and Salter, 2006: 677). In relation to services, and service innovation, the coupling between what is provided and how it is provided is likely to be tighter, due to the inherent 'process nature' of services. Although not our main goal, this paper will shed light on the extent to which different types of innovation co-occur, even if we cannot prove that they are inter-dependent.

Service Innovation: Insights from the New Service Development, Service Innovation and Servitization Literatures

To draw out the differences between innovating goods, services and processes, we review the growing literatures on new service development, service innovation and servitization. Much of the literature on new service development and service innovation is based on studies of service businesses and industries, rather than the introduction of service innovations by manufacturers. To a significant extent these literatures have sought to highlight how service organisations innovate differently from the received understanding of innovation which has largely been derived from studies of technological product and process (TPP) innovation in manufacturing (Miles, 2006). Johne and Storey (1998), for example, note that a recurring theme of the new service development (NSD) literature is that the development of new services is different from the development of new goods. In the context of manufacturing, these differences may be exaggerated for two reasons: first because the literature has tended to emphasise the differences rather than the similarities; and second because manufacturers may innovate services differently from how pure service firms innovate. Drawing on their manufacturing mindset and routines, they may seek to innovate services in a similar way to the way in which they innovate physical products.

Overall, and notwithstanding the caveats outlined above, various themes emerge from the literatures on new service development and service innovation which should sensitise us to how service innovation amongst manufacturers can be expected to compare with (and differ from) goods and production process innovation.

First, it is recognised that service innovation is, like goods innovation, a form of product innovation. As such, it is primarily oriented to addressing customer's needs, rather than achieving optimal efficiency. Baines et al. (2009, see also Gebauer et al., 2005), for example, argue that manufacturing firms with a strong service orientation are often willing to maintain excess capacity, and therefore some apparent inefficiency, in order to enhance customer satisfaction. This is because, unlike physical products, service outputs cannot be stocked; only the demand for a service can be 'stocked' as customers wait to be served, at some cost, including inconvenience, to themselves. Service providers therefore tend to have a different attitude to capacity utilisation, maintaining excess capacity, or having the ability to expand and contract capacity rapidly, particularly where demand is unpredictable and/or customers place high value on having their needs met at their convenience. This contrast with classic manufacturing production operations, where the ability to stock outputs for later sale means that firms seek to achieve high capacity utilisation, particularly of expensive resources (Hayes and Wheelwright, 1984). Overall, this suggests that firms with an external, customer or market orientation will be more likely to innovate services, and/or material products, whilst those with an internal orientation will be more likely to focus on process innovation.

In part because of their intangible or immaterial nature, services are generally considered to be highly interactive, and even co-produced by the provider and the customer or client acting together. As Miles states: ‘Services [and by extension service innovation] are typically interactive, involving high levels of contact between the service provider and the client in the design, production, delivery, consumption and other phases of service activity. This leads to a high degree of customisation to particular client needs.’ (Miles, 2006). Similarly, Johne and Storey (1998: 186) argue: ‘nearly all service products involve close interaction with customers. Interaction is the distinguishing feature of service offerings’. Meanwhile, the servitization literature emphasises that, rather than focus on producing and selling in volume, servitized firms often focus on understanding and satisfying particular users’ needs, which may be idiosyncratic, and their new services may be highly tailored to these customer needs and indeed often co-developed with them. Furthermore, testing, refinement and improvement to new services is done ‘in the field’ with the customer (Baines et al., 2009). These findings are derived from case studies, which may reflect extreme forms of servitisation, but overall the literature indicates that user-producer interactions are especially important in the development of new services. We therefore anticipate that firms with strong connections to their customers, as collaborative partners in innovation projects and/or as important sources of information for innovation will be more likely to develop service innovations. Furthermore, because the development of service innovations typically requires close engagement with the customer, it is less likely than goods innovation to favour firms that are engaged in international markets (other things, such as firm size, being equal).

As mentioned, service innovation is a form of product innovation, and there is a substantial literature from marketing which finds that firms with a market orientation (Narver and Slater, 1990; Slater and Narver, 1995) and which invest in marketing are more likely to introduce new products (e.g., Millson et al., 1992; Atuahene-Gima, 1996; Li and Atuahene-Gima, 1999).[1] We therefore anticipate that firms that invest in marketing activities (to discover user needs and to promote their innovations) will be more likely to introduce goods and service innovations. We suspect that the association between engaging in marketing and innovation may be weaker for the development of service than goods innovations, however, as the more intimate approach to developing services outlined above implies these tend to be propagated by developing relationships rather than through more conventional goods oriented market research and advertising activities.

A recurrent finding in the literature is that R&D typically plays little or no role in innovating services. Miles (2006, 446) claims 'services innovation is rarely organized in terms of the "standard" models of R&D management structures, and is typically conducted on a more ad hoc, project management basis.'[2] Sundbo (1997: 450) concurs, finding that 'service firms innovate on the basis of quick ideas, not from scientific results, and they develop innovations in ad hoc organizations, not in permanent R&D departments'. Meanwhile, Tether and Tajar (2008) found that whilst the classic R&D mode of innovation is clearly apparent and most prevalent in high technology manufacturing, a different mode of innovation based on organisational cooperation is much more widespread in services. If manufacturers tend to innovate services in a similar way to service firms, then we anticipate that R&D will play little or no role in the development of service innovations. By contrast, we anticipate that engaging in R&D will significantly enhance the likelihood that manufacturers introduce goods innovations

Human capital is generally considered important to innovation, including service innovation, but there are indications that the nature of human capital used for service innovation may differ from that required for goods (and production process) innovation. As Johne and Storey (1998) put it: 'New service development relies on the expertise and cooperation of individuals working in teams during and after development'. Because services are often delivered directly or indirectly by people, it is important for front line staff to understand the nature of the new offer and how they are expected to deliver it; for example, the extent to which they can exercise discretion. 'The development of new service offers requires that careful attention be paid to person-to-person skills in supplier organizations' (Johne and Storey, 1998: 188). The servitization literature also emphasises that value is delivered through the relationship, rather than fully embodied into physical products, and that this typically requires employees to develop stronger 'people skills'. Whereas in classic manufacturing production operations, human operatives are likely to be considered a source of unwanted variance hindering conformity, in service operations value tends to be delivered through skilled workers with good customer interface and communications skills; workers are required to have both high levels of product knowledge and an ability to manage and develop on-going relationships (Baines et al., 2009: 510). The move towards services is therefore thought to affect the mix of intra-firm skills, which can be addressed by recruiting different types of people (i.e., those with greater 'soft' or 'people skills') and/or by investing more in training (AEGIS, 2002). For these reasons, we anticipate that firms with greater non-technical human capital, and those that invest more heavily in training, will be more likely to be develop service innovations.

Finally, firm age and size may be influential in the decision to innovate services. If service innovation is less likely to involve R&D (which, due to cost spreading, tends to be undertaken by larger firms (Cohen, 1995)), and if services are inherently difficult to scale (Baines et al., 2009), then large firms may have few advantages over their smaller counterparts when it comes to innovating services. Indeed, smaller firms may have advantages in their ability to forge close and attentive relations with customers. Meanwhile, Bullock (1983, see also Connell and Probert, 2010) proposed a 'soft-to-hard' model, with new firms often starting out by offering 'soft' services through which they learn and earn income, before moving to the development of 'hard' products, which are scalable. For these reasons, we suspect service innovation may be more commonplace amongst new and small firms, or at least that firm size will have less of an influence on service than on goods and process innovation.

Service Innovation and Performance: Innovative Sales and Total Sales

The effects of different types of innovation on firm performance have received significant attention in recent years (see Robin and Mairesse, 2009; Polder et al., 2009; Griffith et al., 2006). None of these studies has however examined service innovation as a distinct type of innovation, considering it instead as an undistinguished form of product innovation.

Regarding the impact of product and process innovations on productivity, the results are mixed.[3] In a cross-country study for the period 1998-2000, Griffith et al. (2006) found a positive impact of product innovation for France, Spain and the UK, and of process innovation for only France. In a more recent study, however, Robin and Mairesse (2009) found that in French manufacturing the driver of labour productivity shifted from process to product innovation between 1998-2002 and 2002-2004. For the UK, and drawing on UK Innovation Survey data, Criscuolo and Haskel (2003) found that process innovations was more likely to increase total factor productivity growth, for the 1994-1996 period, but not for 1998-2000 (OECD, 2009). Hall et al. (2008) also found that process innovation slightly increased labour productivity amongst Italian firms, whilst amongst Dutch firms Polder et al. (2009) found that product and process innovations only have a positive impact when they are combined with organisational innovation.

In light of these mixed results from various empirical studies, we tentatively expect a positive effect on innovative sales from product innovation, including both goods and services, and expect that all forms of innovation will be associated with higher productivity (i.e., sales per employee). Although we have few priors on which to predict the impact of service innovation, the servitization literature (Wise and Baumgartner, 2009; Slack, 2005) indicates that that service innovation, particularly when combined with goods innovation, will increase sales per employee.

3. Data and Empirical Methods

Data Sources

This paper draws on data from two consecutive waves of the UK Innovation Survey, those undertaken in 2005 and 2007 (i.e., UKIS-2005 and UKIS-2007). The 2005 survey covers innovation related activities in the 2002-2004 period, whilst the 2007 survey covers the 2004-2006 period. With the exception of a few alterations due to changes in the enterprise population, the surveys were sent to the same 28,000 enterprises. Although voluntary, both surveys achieved a response rate of over 50 per cent (DIUS, 2008).

The UK Innovation Surveys are based on the core European Community Innovation Survey (CIS) that is co-ordinated by Eurostat, and which itself is based on general guidelines set out in the OECD's 'Oslo Manual' (OECD, 2005). CIS surveys are 'subject-based'; that is, the unit of analysis is the firm, and the firm answers questions directly about its innovation activities, including the sources of innovations and information used to innovate, the effects or impacts of innovation, the barriers to innovation, its use of intellectual property protection, and other matters.

UK Innovation Surveys are conducted by the Office for National Statistics (ONS), the UK's National Statistical Agency, on behalf of the Department for Business Innovation and Skills of the UK Government. The surveys cover enterprises with 10 or more employees whose primary activity is recorded as being in sections C-K of the 2003 Standard Industrial Classification (SIC). For manufacturing firms (i.e., those whose primary activity is recorded as being in Section D of the SIC), the achieved sample was 4,923 firms in the UKIS-2005 and 4,664 firms in the UKIS-

2007; 2,272 manufacturing firms responded to both these surveys, providing the panel dataset that is used in this paper. We have checked for potential selection biases for panel membership and no systematic biases have been found.[4] We use the panel element of these datasets to avoid the problems of simultaneity and common method bias inherent in cross sectional analyses. In particular, we source data for the dependent variables (such as types of innovations introduced, and performance in terms of innovative sales and total sales) from the second survey (UKIS-2007), whilst drawing the independent variables from the first survey (UKIS-2005).

Modelling Part 1 – the Determinants of Service Innovation

Dependent Variable

The first objective of this paper is to examine the determinants of service innovations in manufacturing firms, comparing these with the determinants of material goods innovation and production process innovation. The dependent variables are derived from the answers given to three questions on the UKIS-2007. These asked the firm whether, over the three year period between 2004 and 2006, it had introduced any new or significantly improved goods, services and/or processes for producing or supplying products. A new good may have been a consumer good (such as a new mobile phone) or an intermediate good (e.g., a diagnostic instrument); a new service may have been a new repair and maintenance arrangement, or a new training service; whilst a new process may have involved the use of advanced machinery in production or a new supply practice, such as inventory monitoring or linking of Computer Aided Design to component suppliers. The innovations need not have been new to the industry or market in which the firm operates; they need only to have been new to the firm that introduced them. In other words, the innovations identified were often imitative of those already introduced by other firms.

Table 1 (see Appendix for the Tables) provides some descriptive statistics regarding the extent of innovation behaviour amongst the manufacturing firms that responded to the two surveys, and for the subsample of firms that responded to both. Around 55% of the firms did not claim to have introduced any of the three types of innovation examined here, a share that was slightly higher in the later period. In general, similar proportions of firms claimed to have introduced the various types of innovation over the two periods. The most frequent innovation type was goods (c.35%), followed by the process innovations (c.25%), with service innovation the least widespread (c.14%). This suggests that the service innovation remains relatively uncommon amongst UK manufacturers.

Independent Variables

The independent variables in this study relate to a variety of innovation related activities that firms may or may not have engaged in. This information is drawn from the first survey (i.e., UKIS-2005), which was undertaken two years earlier than the survey from which the dependent variables are drawn.

The external and internal orientation of the firms' innovation activities is derived from a question which asked about the importance of various 'effects' of innovation. These are measured between 'not relevant' (scored 0) and very important (scored 3). Following Belderbos et al's (2004) similar classification, we identify a sub-set of these as being associated with an external, market orientation: i.e., increasing the range of goods or services, entering new markets or increasing market share, and improving the quality of goods or services (Cronbach's Alpha = 0.83). And we identify another sub-set: improving the flexibility of production or service provision; increasing capacity for production or service provision; and reducing unit costs of production or provision, as being associated with an internal orientation (Cronbach's Alpha = 0.86). In each case, the scores on the three items are summed, allowing the aggregated external and internal orientation score to vary between zero and nine.[5]

Engaging with customers is measured by two variables derived from two survey questions. The first concerns whether or not the firm had one or more active co-operative arrangements for innovation with clients or customers during the three year period between 2002 and 2004. The questionnaire stresses that both parties do not need to have benefited commercially, and that pure contracting out work is excluded. Overall, just 14.5% of the firms had cooperative arrangements for innovation with their customers. The second question asks about the importance of various sources of information the firm may have used in its innovation activities.[6] These are ranked by importance (providing ordinal variables), from 'not used', through 'low' and 'medium' importance, to 'high importance'. Overall, 78% of firms used customers as a source of information for innovation, with 34% identifying customers as a source of high importance.

To measure supplier engagement, we draw on the same information as used in relation to customer engagement, simply replacing items in each question pertaining to customers with those pertaining to suppliers. Overall, just 15% of the firms had cooperative arrangements for innovation with their suppliers, whilst 77% had used suppliers as a source of information for innovation, with 21% identifying them as an information source of high importance.

The extent of a firm's financial commitment to innovation is likely to have an impact on the introduction of innovations, regardless of type, and we therefore include an innovation intensity measure, which is the firm's total innovation expenditure (including internal activities such as R&D and acquired knowledge and technologies) divided by its total employment.

Like other CIS, the UK Innovation Surveys also ask whether or not firms engaged in a set of innovation related activities, including: intramural R&D; all forms of design (other than those included with R&D); innovation related marketing activities, such as market research and launch advertising; the acquisition of machinery, equipment and software related to innovation; and training directly related to the development or introduction of innovations. All of these were entered as independent, dummy variables.[7] We combined the remaining two types of innovative activities, the acquisition of extramural R&D and the acquisition of external knowledge, into a single dummy variable. This aggregated variable was still the least frequent of these activities, occurring in about 28% of firms, whilst around half the firms had engaged in intra-mural R&D, and nearly two-thirds (63%) had acquired machinery, equipment or software in relation to innovation.

We included human capital through two variables, one for graduate scientists and engineers as a share of the total workforce, the other for other graduates as a share of the total workforce. We anticipate that the employment of other graduates may be related to the introduction of service innovations.

The influence of the appropriability regime in which the firm operates is examined by incorporating a (SIC3 digit) sector-specific indicator of the appropriability conditions. This was constructed using the average effectiveness of the formal intellectual property protection methods reported by innovating firms in each 3 digit SIC industry. The effectiveness of formal protection is calculated as the sum of the average scores accorded to the use of patents, registered designs, trademarks and copyrights (Cronbach's Alpha = 0.90 at the firm level).

Lastly, we include firm size (measured by the log of employment to reduce skewness), ownership (i.e., whether the firm is independent or part of a wider group of businesses), engagement in international markets, whether the firm is ‘new’ (defined as having been established on or after 1st January 2000), and set of 2 digit industry dummies to control for variations by industry.

Modelling Part 2 – Performance effects of service innovation

The second objective of the paper is to examine the performance effects of different types of innovation, and in particular the impact of service innovation on innovative sales and total sales. Here, we consider a conventional output production function, linking output (sales and innovative sales) to inputs (here the firm size), and the firm’s knowledge level. We measure a firm’s knowledge level by its introduction of different types of innovations, i.e. goods, services, and/or process innovations in the 2002-2004 period (and reported in UKIS-2005). The output measures, total sales and innovative sales, relate to 2006 and are drawn from the second survey (i.e., UKIS-2007), allowing us to avoid problems of simultaneity and endogeneity. We also control for new firms, by introducing a dummy variable for firms that were established after 1st January 2000; and, separately, for firms belonging to a wider company group. Sectoral variations are also taken into account by dummy variables.

4. Statistical Model and Results

Multivariate Probit Estimation Methodology

We began with a multivariate probit model that jointly estimates the factors associated with engaging in the three types of innovation: goods, processes and services:

$$y_{(i,k)} = \begin{cases} 1 & if \;\; x_{i,k}\beta_k + \omega_{i,k} > 0 \\ 0 & otherwise, \qquad\qquad k = good, process, service;\; i = 1,...,N \end{cases}$$

where $(\omega_1\omega_2\omega_3) : N(0,\Sigma)$ with Σ being the covariance matrix of the error terms. The multivariate probit specification allows for systematic correlations between engaging in the different types of innovation. If a correlation exists, estimates of separate equations for each type of innovation would be inefficient and possibly misleading. The three-equation system is estimated by simulated maximum likelihood using the Geweke-Hajivassiliou-Keane (GHK) simulator due to the occurrence of multiple integrals (Geweke, Keane and Runkle, 1997). The results have been obtained with a Stata routine implemented by Cappelari and Jenkins (2003) and are based on 100 draws. The method also allows us to test for independence between the innovation types. An absence of independence implies they are inter-related, and possibly complementary, although this is not a definitive test of complementarities (Cassiman and Veugelers, 2006).

As outlined earlier, to take advantage of the panel nature of our data, and to avoid the problems of simultaneity and common method biases inherent in cross sectional analysis, we use the first survey for the explanatory variables and the second for the dependent variables. Another problem which can arise in the analysis of knowledge production is selection bias.[8] We performed a non-parametric test for the presence of selection bias (Hall et al., 2009, Das et al., 2003), as well as a two-stage Heckman estimation. Both results indicate that selection bias is not a concern.[9]

Results: Determinants of Different Innovation Strategies

The results of the multivariate probit analysis are provided in Table 3.[10] We discuss the results in three groups: those that align with our prior expectations, those that partially align, and those that do not conform to our priors.

As expected, firms with an external, market orientation were more likely to innovate, especially in goods, with a weaker but still positive and significant result for service innovation. Moreover, an external, market orientation did not increase the propensity to introduce process innovations. Instead, and in line with expectations, an internal orientation was positively and significantly associated with the introduction of process innovations. This was negatively associated with goods innovations, but had no significant impact on service innovation.

Innovation intensity was, as expected, positively related to the introduction of all three types of innovation. Engaging in R&D had a positive and significant impact on the propensity to introduce goods innovation, but had no significant impact on either service or process innovations. The same is true of investments in design and other external knowledge acquisition. Also notable here is that the strength of the appropriation regime had a weakly significant impact on the propensity to introduce goods innovations, but no impact on either service or process innovations. By contrast, investments in training were positively and significantly related to the introduction of service and process innovations, but not goods innovations. Meanwhile, firms that invested in marketing were significantly more likely to introduce goods and, to a lesser extent, services innovations, but marketing had no significant effect on process innovations. These results conform to our prior expectations.

The results for firm size are also in line with our prior expectations, in that we find the strongest relationship is between size and process innovation, with a positive but weaker result for goods innovation. We find no significant relationship between firm size and service innovation. This suggests that smaller firms are not disadvantaged in the introduction of service innovations relative to their larger counterparts. Also interesting is that whilst firms that are engaged in international markets are more likely to introduce goods and (less strongly) process innovations, this is not the case with service innovations. This suggests that firms that focus solely on the domestic market are not disadvantaged in the development of service innovations.

In relation to human capital, we find that the share of scientists and engineers in the workforce is – as expected - positively related to introducing goods innovations. This has no significant impact on either service or process innovation, however. Meanwhile, and contrary to our expectations, we find no evidence that the share of 'other graduates' in the workforce is related to the introduction of service innovations (or indeed to either goods or process innovations).

The most surprising results are found for customer (and supplier) engagement. We had anticipated that firms that had collaborated with their customers, and those that drew strongly on their customers as a source of information for innovation, would be more likely to introduce service (and goods) innovations. We found no evidence to support this. Furthermore, we found no evidence that firms that collaborate with their suppliers and/or use suppliers as an important source of information for innovation were more likely to introduce process innovations. Indeed, the only significant finding that emerged is that, somewhat surprisingly, firms that co-operate with customers were more likely to introduce process innovations.

We also found no evidence to support the notion that start-ups are more likely to introduce service innovations. Whether the firm was an independent business or part of a larger group also had no significant impact on its propensity to innovate.

Finally, we note that the correlation coefficients of the error terms in the multivariate probit are all positive and highly significant (See Table 3b). This finding indicates that goods, services and process innovations are not independent, but more likely to be co-incidental and possibly interrelated and complementary. This is indicative rather than a test of complementarities, but is consistent with recent literature that emphasizes the increasing interconnections between goods, services and processes (Kim and Mauborgne, 2004a, 2004b). These correlations indicate that these three types of innovation should be studied within a simultaneous framework, rather than by separate regressions.[11] Interestingly, the strongest relationship was between goods and process innovations.

Overall, the multivariate probit estimation indicates that the resources and behaviours associated with innovating services are different from those associated with innovating goods and processes. In order to explore this further, we estimated a multinomial logit model on exclusive combinations of innovation strategies.

Multinomial Logit Estimation Methodology

To allow each unique combination of innovation types to be estimated separately (i.e., goods only; services only; process only; goods and services; goods and process; service and process; and all three types together, with the base category being none of these), we estimated a multinomial logit model. Formally, this estimates:

$$Prob(Y = j) = \frac{e^{Z_i \delta_j}}{\sum_{k=1}^{7} e^{Z_i \delta_j}}$$

with $j \in$ *{goods (1), services (2), process(3), goods and services (4), goods and processes (5), services and processes (6), all of the three (7)}*

The results of this model are presented in Table 4. A caveat on this analysis is that the number of observations in some categories is quite small: 47 firms introduced both service and process innovations, 50 introduced only service innovations, 61 introduced goods and service innovations; whilst all other categories have at least 150 observations.[12] However, the Wald test for combining indistinguishable outcomes was rejected; all the strategies are statistically distinct, a finding also supported by the Hausman-McFadden test of independence of irrelevant alternatives. The multinomial logit model therefore provides an appropriate model choice.

Some general findings are the following. An external, market orientation to innovation activities is significantly associated with all four categories involving goods innovation. In-house R&D, marketing, and external knowledge acquisition are also associated with goods innovation, on its own or with process innovation. Meanwhile, an internal orientation is particularly associated with process only innovation.[13] Surprisingly, there is no evidence that supply-chain collaborations, or using either customer or suppliers as sources of information, are strongly associated with any type(s) of innovation.[14] The employment of graduate scientists and engineers was associated with greater goods and service, goods and process, and – surprisingly – service only innovation.

For our purposes, three lines of analysis are particularly interesting. Firstly, the factors associated with only introducing service innovations; secondly the difference between 'goods and service' and 'goods only innovation' (i.e., G+S c.f. G); and thirdly the difference between innovating in all three types and innovating both goods and processes (i.e., G+P+S c.f. G+P). We therefore determine the difference by calculating the odds ratios associated with service innovation. These odds ratios allow us to infer the difference in behaviour associated with 'adding service innovation' (i.e., G+S – G = S; and G+P+S – G+P = S).

With regard to innovating only services, and compared with firms that did not introduce any innovations, we find that service only innovators are much more likely to be independent firms (rather than group firms), are much less likely to have engaged in supply-chain cooperations, or to have engaged in international markets. They are significantly more likely to source information for innovation from suppliers (but not customers), and, contrary to Bullock's 'soft to hard' hypothesis (Bullock, 1983), which anticipated that firms often start by offering 'soft' services before moving on to develop 'hard' products, service only innovators are significantly less likely to be young firms. With the understandable exception of having higher innovation intensities, in all other respects service only innovators did not differ significantly from non-innovators.

In relation to the impact of 'adding services', our analysis finds relatively few differences. However, firms that engaged in internal R&D were significantly less likely to innovate services in addition to innovating goods (and processes), whilst those that engaged in training were significantly more likely to introduce service innovations in addition to goods (and process) innovations. Furthermore, firms which engaged in international markets were significantly less likely to innovate services in addition to goods innovations. In all other respects, the characteristics and behaviours of firms that innovated services did not differ significantly from those that also innovated goods (and processes).

Overall, these findings indicate that innovating services may be an innovation trajectory that is particularly attractive to independent firms that do not have the resources to engage in R&D. Our results also indicate that, compared to that of goods-oriented firms, services innovators have less of a technological orientation, and instead make greater investments in training.

Performance Impacts of Innovating Services

Table 2 presents the distribution of innovative and total sales by different innovation types. Firms that innovate in both goods and services tend to have higher innovative sales than firms that introduced innovative goods but not services, or services but not goods. However, a closer look shows that the differences in means between categories are not always significant. [15] Although we found in the previous section that different innovation types are associated with different behaviours, their performance effects may not be distinct.

Table 6 shows the impact of different innovation types on innovative sales. We use three different specifications: innovative sales per employee, total innovative sales and categories of innovative sales. Accordingly, we also use three different econometric models, which are ordinary least squares for the innovative sales per employee, a censored regression model (tobit) given the truncated nature of innovative sales, and an ordered logistic model for the share of innovative sales' categories. Innovative sales are here defined as sales due to new or significantly improved products, where products include both goods and services. The results are consistent across the different specifications.

We find that, with the understandable exception of 'only process innovation', all types of innovation strategies increase innovative sales, and innovative sales per employee. In more detail, the results show that innovating goods, independently or alongside services and processes has the largest impact, and whilst innovating services only has a small positive effect on innovative sales. Moreover, a closer look shows that innovating goods and innovating both goods and services have a similar effect; statistically they can be combined. This is also the case for innovating in goods and processes, and innovating in all three categories. These findings suggest that new goods drive innovative sales in manufacturing firms, and that adding service innovation to goods innovation appears to have no additional impact on innovative sales or innovative sales per employee.

We also analyzed performance in terms of total sales and total sales per employee. The results show that innovating only services, and innovating services and goods, has the greatest impact. We also find a positive impact for size on total sales and its productivity. However, t-tests on equality of coefficients indicate a rather different categorization of innovation types, compared to innovative sales. Innovations in goods and in processes can be combined with innovations of all three types, whilst innovation in services can be combined with innovation in goods and services. This latter category has a greater effect on total sales than the previous one, which suggests that service innovation plays a key role in increasing total sales (and total sales per employee).

Overall, our results show that whilst service innovation does not seem to increase innovative sales, it is associated with higher total sales and labour productivity. This finding accords with the existing servitization literature, which argues that introducing new services allows manufacturers to increase their revenues.

5. Concluding Discussion and Limitations

To our knowledge, this is the first quantitative empirical study to examine the determinants and effects of service innovation amongst manufacturing firms. The study has shown that manufacturers typically innovate services differently to the way they (typically) innovate goods. So whilst goods and services are both forms of product innovation, it is better to examine them separately. Innovating services also differs from innovating production processes.

In relation to similarities with goods innovation, we anticipated that manufacturers innovating services would tend to: 1. have an external, market orientation (rather than an internal orientation); 2. invest in marketing; and 3. place a strong emphasis on interacting with and learning from customers. We found support for points 1 and 2 but not point 3.

In relation to differences, compared with goods innovations, we anticipated that: 1. engaging in research and development would not be important to innovating services; 2. that investing in training would be more important, whilst 3. firm size would not be important (or less important). We found empirical support for all of these expectations. We also anticipated that stronger non-technical human capital would be important for service innovation, but did not find support for this.

Overall, we find that manufacturing firms tend to take a different approach to innovating services than is typically used to innovate material products (i.e., goods) and production process. Furthermore, our empirical findings support the servitization literature which identifies internal training and marketing as significant activities for the development of new services (White et al., 1999; Gebauer et al., 2005).

Surprisingly, we did not find the anticipated impact of close engagement with customers (and suppliers) on innovation. In general, the new service development and service innovation literatures place considerable emphasis on how close customer-provider engagement stimulates innovation, to the extent that novel services are often thought to be co-innovated, with the provider and customer working closely together. The existing literature is not unanimous on this point, however. Sundbo (1997), for example, found that external networks, including customers, were not important for service innovation, whilst Martin and Horne (1995, cited in Johne and Storey, 1998) found that customer involvement in service product development to be relatively low. Whilst surprising, our results are not therefore unprecedented. Perhaps close customer relations are just as important for knowing when not to innovate as they are for knowing when to innovate.

With regard to the impact of service innovation on performance, we find that although service innovation does not seem to increase innovative sales, it is associated with higher total sales and labour productivity.

A final insight is that we find the three types of innovation studied here are not statistically independent. If a firm innovates in goods, services or processes, it is more likely than otherwise similar non-innovating firms to also innovate in one or both of the others. The strongest correlation was found between goods and process innovations. Previous research has found an increasing number of firms are implementing both product and process innovations (Pine et al., 1993; Adler et al., 1996). However, whilst we have detected co-occurrence, this is not sufficient to prove the innovations are directly inter-related and complementary.

This study and the data upon which it is based have some important limitations. The UK Innovation Surveys are a variant of the Community Innovation Surveys that are undertaken in a large number of European and other countries. These surveys are advantageous to scholars in that they provide large 'ready-made' datasets that have been collected rigorously and at considerable expense, usually by the national statistical agency. The disadvantage of using extant datasets is that they were not designed to answer the specific question of interest to the researcher. In our case, we would ideally like to know much more about the service innovations than the data permits. For example, we would like to be able to distinguish between different types of service innovations (e.g., services done with the client and services done for the client). We would also have liked to know more about the history of the firms, and the extent to which they provide non-innovative services. We would also like to know the extent to which different types of innovation – i.e., goods, services, processes and organisational changes – are actually inter-connected. Because of the nature of the data available to us, the present study often hints at connections that cannot be fully examined. This requires further research, particularly through case studies and/or a bespoke survey of firms.

Notes

1 Interestingly, amongst service firms, Sirilli and Evangelista (1998) found that marketing played a relatively minor role compared to other innovation related activities, although its role was greater amongst some largely consumer oriented services, such as hotels and restaurants, retailing, advertising and post and communications.

2 The main exceptions amongst services are the major telecommunications firms, and those developing packaged software.

3 Note that the following studies are not directly comparable given the differences in their specifications and methodology.

4 The selection bias has been checked by testing the probability of belonging to the panel as a subset of each of the individual surveys. Besides industrial and regional dummies, we also took into account firms' size, ownership characteristics (group or independent firm), main type of customer, and innovation behaviour. The estimation results are available from the authors upon request.

5 We exclude the three other effects – reducing environmental impacts and improving health and safety, meeting regulatory requirements, and increasing value added - as it is ambiguous whether these are externally or internally oriented.

6 The sources of information are categorized into 4 area: internal (within your enterprise or enterprise group), market sources (Suppliers of equipment, materials, services, or software; clients and customers; competitors or other enterprises in your industry; consultants, commercial labs, or private R&D institutes), institutional sources (Universities or other higher education institutions; government or public research institutes) and other sources(conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations; technical, industry or service standards).

7 We choose to use dummy variables, instead of expenditures as the data on expenditures on the individual items is considered unreliable (Mairesse and Mohnen, 2010; Gagnal et al., 2010)

8 Not all firms invest in innovative activities; therefore studies that are restricted to this non-random sample of firms engaged in innovative activities are prone to selectivity bias.

9 The non-parametric test was performed in two stages. First, a probit model of engaging in innovative activities was estimated on a number of firm characteristics. We then recovered for each firm the predicted probability of engaging in innovation and the corresponding Mills' ratio. The recovered predicted probabilities, the Mills' ratio, their square terms and the interaction terms were then regressed on innovation intensity. The results showed that none of these terms were significant. We also performed a two-stage Heckman selection estimation, where the Mills' ratio was to be found insignificant, rejecting once again the presence of selection bias. The estimations for both innovation types and innovation intensity equations are available upon request.

10 No multicollinearity or instability among the variables has been found. The estimation diagnostics and correlation table are available upon request.

11 As a robustness check, we regressed three specifications (not reported) and added respectively firms' choices and innovative behaviour to a basic model with only structural variables. Adding firm-specific effects (from the first specification towards the third) did not decrease the correlations; instead, the residual correlations between the three types of innovation remained persistent and significant. Thus far, we have not identified any contextual variable that might affect the relationship between the different types of innovation: all three types appear to be interrelated and possibly complementary, independent of firms' structural characteristics and behavioural choices.

12 Due to the very small number of firms that cooperate, the variables on cooperation with suppliers and with customers have been aggregated into a single variable.

13 Firms that introduced only goods innovations, and both goods and service innovations (but not process innovations) were significantly less likely to have this orientation.

14 The presence of high coefficient in the 'services and process innovation' models is probably due to the small number of observations. This category had the smallest number of observations (n. = 47), and the results should be interpreted with care.

15 These t-tests are available from the authors upon request.

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APPENDIX

APPENDIX A

Description of Variables

Formal Protection (SIC 3 dgt)	Means of scores of the importance of the formal IP protection' methods used by innovating firms in 3 digit industry.
Being part of a group	1 if the firm is part of a wider company group, else 0
Being a start-up	1 is the firm was established after 1st January 2000
Size	Logarithm of the number of employees
S&E graduates in total employment	Proportion of the firm's employees that were educated to degree level or above in science and engineering subjects.
Other graduates in total employment	Proportion of the firm's employees that were educated to degree level or above in other (non-science and engineering) subjects
Innovation intensity	Total innovation expenditure divided by number of employees
Cooperation with customers (suppliers)	1 if the firm cooperated for innovation with a customer (supplier), else 0
Customers (suppliers) as a source of knowledge	1 if the firm used customers (suppliers) as a source of knowledge, else 0
Internal orientation	Sum of scores on internally oriented innovation objectives (see section on independent variables).
External, market orientation	Sum of scores on external, market oriented innovation objective (see section on independent variables).

Engagement in international markets	1 if the firm sold products in international markets , else 0
Investing in internal R&D	1 if the firm undertook in-house R&D activities, else 0
Acquisition of machinery & equipment	1if the firm invested in the acquisition of machinery and equipment related to innovation, else 0
Investing in training	1 if the firm engaged in training activities related to innovation, else 0
External knowledge acquisition	1if the firm acquired R&D services or invested in the acquisition of external knowledge related to innovation, else 0
Investing in design	1 if the firm engaged in design activities related to innovation, else 0
Investing in marketing	1 if the firm engaged in marketing activities related to innovation, else 0
Innovative sales productivity	Share of the turnover changes due to innovation divided by the total number of employees
Total sales productivity	Total turnover divided by the total number of employees

TABLES

Table 1: Distribution of innovation types in manufacturing firms

	UKIS-2005		UKIS-2007		UKIS-2007 results for UKIS-2005-2007 Panel	
Innovations introduced	Freq.	Percent	Freq.	Percent	Freq.	Percent
No Innovation	2580	52%	2680	57%	1284	57%
Goods	1821	37%	1603	34%	800	35%
Services	729	15%	633	14%	288	13%
Process	1376	28%	1141	24%	565	25%
Total	4923	100%	4664	100%	2272	100%

Table 2: Innovative performance by innovation strategy

			% of sales reported in UKIS 2007 from:			UKIS-2007 Total Sales (in £000)
Innovations introduced in UKIS - 2005	Freq.	Percent	products new to the industry	products new to the firm	significantly improved products	
None	1,148	50.6	1.0	1.8	1.8	17,381
Goods only	339	14.9	4.1	5.8	7.7	26,710
Services only	50	2.2	1.6	3.8	8.4	21,944
Goods & Services	61	2.7	4.8	8.8	6.0	18,689
Process only	155	6.8	0.7	3.2	4.0	26,424
Goods and Process	297	13.1	6.1	8.0	9.9	60,363
Services and Process	47	2.1	2.0	4.4	11.0	17,570
Goods, Services & Process	173	7.6	5.9	6.4	10.2	65,734
Total	2,270	100	2251	2253	2238	28,814

Table 3a: Multivariate Probit Analysis for Innovation Strategies

	Goods innovation	**Service Innovation**	**Process Innovation**
Formal protection (SIC 3dgt)	0.0767*	0.0484	0.0394
	(0.05)	(0.06)	(0.05)
Being part of a group	0.0746	-0.0662	-0.0772
	(0.07)	(0.08)	(0.07)
Being a start-up	0.0667	-0.112	-0.0138
	(0.10)	(0.12)	(0.11)
Size	0.0590**	-0.0313	0.139***
	(0.03)	(0.03)	(0.03)
Internal orientation	-0.052***	0.0112	0.0576***
	(0.01)	(0.02)	(0.02)
External, market orientation	0.0937***	0.0343*	0.0108
	(0.02)	(0.02)	(0.02)
Innovation intensity	0.0395**	0.0308*	0.0512***
	(0.02)	(0.02)	(0.02)
Engaging in international markets	0.179***	-0.116	0.138*
	(0.07)	(0.08)	(0.07)
Internal R&D	0.297***	0.0958	0.0476
	(0.07)	(0.09)	(0.07)
Acquisition of machinery & equipment	0.0096	-0.0095	0.0057
	(0.08)	(0.09)	(0.09)
Investing in training	-0.0266	0.207**	0.276***
	(0.07)	(0.08)	(0.07)
External knowledge acquisition	0.208***	0.0066	0.0754
	(0.07)	(0.08)	(0.07)
Investing in design	0.173**	0.0461	0.118
	(0.07)	(0.08)	(0.07)
Investing in marketing	0.235***	0.150*	-0.0095
	(0.07)	(0.09)	(0.08)
S&E graduates / Total employment	0.0061**	0.0032	0.0024
	(0.00)	(0.00)	(0.00)
Other graduates / Total employment	0.0003	0.0013	-0.0039
	(0.00)	(0.00)	(0.00)
Suppliers as a source of knowledge	0.0431	0.0287	0.0490
	(0.04)	(0.05)	(0.04)
Customers as a source of knowledge	-0.0290	-0.0016	-0.0584
	(0.04)	(0.04)	(0.04)
Cooperation with suppliers	0.0281	0.0134	-0.0019
	(0.13)	(0.16)	(0.13)
Cooperation with customers	0.0897	-0.0160	0.238*
	(0.14)	(0.16)	(0.13)
Constant	-1.592***	-1.487***	-1.917***
	(0.17)	(0.19)	(0.17)

Notes to Table 3a:*Significant at 10%; ** significant at 5%; *** significant at 1%. Industry control variables were included but not reported. Standard errors are in parentheses.

Table 3b: Multivariate Probit Analysis for Innovation Strategies – Statistics

	Rho1	**Rho2**
Rho2	1.171***	
	(0.08)	
Rho3	0.726***	0.627***
	(0.05)	(0.05)
Number of draws	100	
Number of observations	2206	
Aic	5676.77	
χ2	741.11	
p	0.000	

Table 4: Multinomial Logit Analysis - Combinations of Innovation Strategies

	Goods only	**Service only**	**Process only**	**Goods & Service**	**Goods & Process**	**Service & Process**	**All 3 Types**
Formal protection (SIC 3dgt)	0.179*	0.468	0.127	0.320	0.198	0.266	-0.0439
	(0.10)	(0.42)	(0.13)	(0.20)	(0.13)	(0.37)	(0.16)
Being part of a group	0.136	-1.834*	-0.241	0.124	0.0283	-1.006	0.0251
	(0.17)	(1.01)	(0.22)	(0.25)	(0.19)	(0.91)	(0.21)
Being a start-up	0.103	-0.649	-0.193	-0.176	0.262	-15.08	-0.0908
	(0.24)	(0.88)	(0.32)	(0.36)	(0.26)	(0.65)	(0.33)
Size (log of employment)	0.0743	-0.200	0.246***	-0.108	0.328***	0.252	0.101
	(0.06)	(0.28)	(0.08)	(0.12)	(0.07)	(0.35)	(0.08)
Internal orientation	-0.166***	0.213	0.159***	-0.0939*	0.0114	0.0763	0.0350
	(0.03)	(0.15)	(0.05)	(0.05)	(0.04)	(0.13)	(0.04)
External, market orientation	0.189***	0.0380	-0.0546	0.150**	0.157***	-0.0462	0.116**
	(0.04)	(0.10)	(0.05)	(0.06)	(0.05)	(0.14)	(0.05)
Innovation intensity	0.0395	0.225	0.0498	0.0341	0.131***	0.147	0.0832
	(0.04)	(0.18)	(0.05)	(0.06)	(0.04)	(0.13)	(0.05)
Engaging in international markets	0.582***	-0.582	0.335	-0.239	0.518**	-0.172	0.135
	(0.17)	(0.65)	(0.21)	(0.25)	(0.21)	(0.79)	(0.20)
Internal R&D	0.675***	0.625	-0.148	0.216	0.607***	0.168	0.230
	(0.18)	(0.63)	(0.22)	(0.27)	(0.20)	(0.71)	(0.20)
Acquisition of machinery & equipment	0.227	-0.465	0.166	-0.169	-0.0820	0.638	0.0113
	(0.20)	(0.79)	(0.29)	(0.28)	(0.22)	(0.77)	(0.26)
Investing in training	-0.380**	-0.278	0.608***	0.264	0.0934	1.440*	0.536**
	(0.18)	(0.63)	(0.22)	(0.28)	(0.19)	(0.78)	(0.23)
External knowledge acquisition	0.303*	0.110	-0.0466	0.155	0.475***	-14.70***	0.179
	(0.18)	(0.63)	(0.22)	(0.26)	(0.17)	(0.50)	(0.21)
Investing in design	0.197	-0.888	0.140	0.408	0.350*	-0.122	0.289
	(0.18)	(0.62)	(0.22)	(0.28)	(0.18)	(0.84)	(0.20)
Investing in marketing	0.399**	0.282	-0.232	0.476	0.221	-0.888	0.328*
	(0.18)	(0.60)	(0.25)	(0.29)	(0.19)	(1.09)	(0.19)
S&E graduates / Total emp.	0.00915	0.0338**	0.00509	0.021***	0.0153**	-0.0850	0.0032
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.13)	(0.01)
Other graduates / Total emp.t	0.0001	0.0024	-0.0171*	0.00682	-0.001	-0.0063	-0.004
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
Suppliers as a source of knowledge	-0.0207	0.427	0.0225	0.129	0.211*	-0.180	0.0789
	(0.10)	(0.39)	(0.12)	(0.16)	(0.11)	(0.28)	(0.11)
Customers as a source of knowledge	0.0389	-0.546	-0.0423	-0.0157	-0.255**	0.0710	-0.0279
	(0.09)	(0.37)	(0.12)	(0.16)	(0.11)	(0.31)	(0.10)
Supply-chain cooperation$	0.0325	-1.025	0.163	-0.141	0.210	-13.89***	0.270
	(0.19)	(1.31)	(0.24)	(0.29)	(0.18)	(0.56)	(0.21)
Constant	-3.659***	-4.828***	-4.270***	-3.742***	-5.405***	-5.924***	-3.999***
	(0.41)	(1.67)	(0.49)	(0.66)	(0.49)	(1.91)	(0.55)

*Significant at 10%; ** significant at 5%; *** significant at 1%.$ - supply chain cooperation is cooperation with either or both customers or suppliers.

Table 5: Odds ratio for adding innovative services

Odds for introducing service innovation compared with ...	No innovation	goods only innovation	goods and process innovation
Formal protection (SIC 3dgt)	1.597	1.151	0.785
Being part of a group	0.159***	0.989	0.997
Being a start-up	0.523**	0.756	0.702
Size (log of employment)	0.819	0.833	0.796
Cost orientation	1.237	1.070	1.024
Market orientation	1.039	0.962	0.960
Innovation intensity	1.253**	0.995	0.954
Serving international markets	0.558***	0.440***	0.682
Internal R&D	1.867	0.632**	0.686***
Acquisition of machinery & equipment	0.628	0.673	1.098
Investing in training	0.757	1.904*	1.557***
External knowledge acquisition	1.116	0.862	0.744
Investing in design	0.412	1.234	0.941
Investing in marketing	1.326	1.080	1.114
Suppliers as a source of knowledge	1.533***	1.161	0.877
Clients as a source of knowledge	0.580	0.947	1.255
Cooperation	0.358**	0.841	1.062
Scientist & engineers/Total employment	1.034	1.012	0.988
Non-scientific higher education/Total employment	1.002	1.007	0.997

*Significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Performance effects of innovation types

	Innovative Sales			Total Sales
	Productivity	**Share**	**Categories**	**Productivity**
Size	-0.515***	1.030***	0.0590	0.517***
	(0.06)	(0.18)	(0.04)	(0.02)
Goods only	2.269***	6.581***	1.496***	0.178***
	(0.23)	(0.58)	(0.14)	(0.06)
Services only	1.596***	5.437***	1.399***	0.386***
	(0.50)	(1.27)	(0.32)	(0.12)
Process only	0.308	1.779**	0.412*	0.202**
	(0.28)	(0.83)	(0.23)	(0.09)
Goods and Services	2.302***	6.589***	1.533***	0.344***
	(0.48)	(1.12)	(0.26)	(0.12)
Goods and Process	3.181***	7.948***	1.874***	-0.0212
	(0.27)	(0.61)	(0.16)	(0.07)
Services and Process	1.677***	5.614***	1.100***	0.283**
	(0.51)	(1.29)	(0.40)	(0.12)
All three	2.995***	7.820***	1.867***	0.137*
	(0.31)	(0.71)	(0.18)	(0.08)
Being part of a group	0.281*	0.570	0.157	-0.0529
	(0.16)	(0.46)	(0.12)	(0.05)
Being a start-up	0.00471	0.0737	0.108	0.266***
	(0.22)	(0.66)	(0.16)	(0.07)
Industry dummies	*yes*	*yes*	*yes*	*yes*
F-test for industry dummies	1.26	1.35	38.07	17.68
Prob>F	0.19	0.13	0.01	0
Regional dummies	*yes*	*yes*	*yes*	*yes*
F-test for regional dummies	1.36	1.24	7.5	2.42
Prob>F	0.19	0.25	0.67	0.01
N	2270	2270	2249	2270
R-Squared	0.30			0.95
F	30.33			1499.35
$\chi 2$		531.22	346.50	
Model	*OLS*	*Tobit*	*Ordered logit*	*OLS*

Notes: Coefficients significant at 1% ***, 5%** and 10%*. Standard errors are in brackets. The log transformation of innovative sales has been used in the first specification.

Table 7: Aggregated performance effects: Innovative Sales

	Innovative Sales		
	Productivity	**Share**	**Categories**
Size	-0.505***	1.062***	0.0618
	(0.06)	(0.18)	(0.04)
Goods and G&S	2.227***	6.309***	1.448***
	(0.21)	(0.54)	(0.13)
G&P and all three	3.061***	7.609***	1.813***
	(0.21)	(0.51)	(0.13)
Services and S&P	1.595***	5.255***	1.204***
	(0.36)	(0.93)	(0.26)
Being part of a group	0.284*	0.572	0.162
	(0.15)	(0.46)	(0.12)
Being a start-up	0.00194	0.0594	0.115
	(0.22)	(0.66)	(0.16)
N	2272	2272	2251
R-Squared	0.30		
F	32.68		
$\chi 2$		525.53	344.86
Model	*OLS*	*Tobit*	*Ordered logit*

Notes: Coefficients significant at 1% ***, 5%** and 10%*. Standard errors are in brackets. The log transformation of innovative sales has been used in the first specification.

Table 8: Aggregated performance effects: Total Sales

	Total Sales Productivity
Size	0.517***
	(0.02)
Goods and Process and All three	0.171***
	(0.05)
Services and G&S	0.359***
	(0.08)
Being part of a group	-0.0568
	(0.05)
Being a start-up	0.266***
	(0.07)
N	2272
R-Squared	0.95
F	1697.87

Notes: Coefficients significant at 1% ***, 5%** and 10%*.