PUBLISHED IN INDUSTRIAL AND CORPORATE CHANGE, 21(5): 1255-1281, 2012

# The benefits of R&D and breadth in innovation strategies: A comparison of Finnish service and manufacturing firms

Aija Leiponen
Imperial College Business School
Imperial College London
United Kingdom
and
Cornell University
Dyson School of Applied Economics and Management
Ithaca, NY 14853-7801
United States
aija.leiponen@cornell.edu

**ABSTRACT**

This empirical study compares the determinants of innovation in manufacturing and services through descriptive and regression analyses of sales from innovative products and services. A particular focus is on the effects of R&D investments and breadth in knowledge sourcing and innovation objectives. The results suggest that, contrary to earlier research, R&D investments play a statistically and economically significant role in service innovation. We suggest that this results from the growing engagement of service firms in regular R&D activity. Both service and manufacturing firms also benefit from breadth in external knowledge sourcing strategies. In contrast, breadth in terms of pursuing parallel innovation objectives appears to have detrimental effects on innovation in service industries. We interpret the latter results through reference to service firms' R&D management capabilities: Managing multiple innovation projects is challenging, and some service firms may not have accumulated the requisite managerial processes and capabilities to benefit from these strategies. The available data provide support for this conjecture. The detrimental effects of breadth in innovation objectives are significantly mitigated by regular R&D activities.

## 1. INTRODUCTION

This paper examines the use of innovation strategies such as R&D, knowledge sourcing, and innovation objectives, and their relationships with innovation outcomes, comparing service and manufacturing firms. Most scholarly studies of innovation continue to focus on manufacturing firms and industries. In light of the economic importance of the service sector, a much greater attention on innovation in services is appropriate. Around 75% of GDP in industrialized economies is now produced in the service sector (CIA, 2009), yet we do not understand very well how the sector renews itself. Moreover, the boundaries between services and manufacturing are getting blurred (Christensen & Drejer, 2007). Much innovation in the manufacturing sector actually involves service activities, and many physical goods are starting to be offered as services through the "power by the hour" business model. Analyses of service innovation may thus also illuminate aspects of innovation processes in the manufacturing sector.

Traditionally, and perhaps going all the way back to Adam Smith's discussion of "unproductive labor" in certain types of services (as cited in Gallouj and Savona 2009: 151), service industries have been perceived as lagging in terms of innovativeness and productivity growth, which is feared to slow down economic dynamism (e.g., Baumol, 1967; Pavitt, 1984; Cohen and Zysman, 1987). At the same time, services are expected to be the engine of employment growth in industrialized economies in the coming decades (OECD, 2005). In the OECD area, much of this growth already takes place in the service sector. Telecommunications, transport, wholesale and retail trade, finance, insurance and business services together account for about 60% of all employment created in the OECD area (OECD ibid: p. 6; also see Evangelista and Savona, 2004, for a detailed analysis of the Italian service sector). For both of the above perspectives on the service economy, innovation appears to be a central concern.

This paper seeks to highlight the role played by R&D and “breadth” in innovation strategies in service innovation. Patterns of innovative search have been explored almost solely in the manufacturing context (e.g., Rosenkopf and Nerkar, 2001; Katila and Ahuja, 2002; Laursen and Salter, 2006; Leiponen and Helfat, 2010), even though external search is viewed as a key strategic consideration in the global deregulated economy (Chesbrough, 2003; Mowery, 2009; among many others). It seems that these key strategies should also be examined in the service context. A stream of earlier studies emphasized the differences in the organization of innovation between service and manufacturing firms (e.g., Miles, 1993; Sundbo, 1997). Later studies came to call this stream the “demarcation” view on service innovation (Coombs and Miles, 2000; Tether, 2005). Here, we build on recent efforts toward a synthesis (e.g., Drejer, 2004; Gallouj and Savona, 2009) that seek to construct a more holistic understanding of innovation that has room for innovation processes that result in both physical goods and service products. Considering the potential differences between service and manufacturing innovation processes, there appears to be a research gap to investigate whether breadth in innovative search influences innovation outcomes similarly in service and manufacturing industries.

An earlier, closely related study investigated the effects of the breadth of innovation objectives and information sourcing strategies on innovation outcomes using data on the manufacturing sector only (Leiponen and Helfat, 2010). In the current study, we use the second Finnish Community Innovation Survey (CIS2) dataset combined with a subsequent R&D survey to statistically compare the determinants of innovation between a set of service industries (excluding personal services) and manufacturing industries, and between different subsectors within services and within manufacturing. The two sources of information enable the construction of a dataset where independent variables are lagged by two years. A lagged dependent variable is also included to control for otherwise unobservable innovation capabilities. The sub-sector level analyses enable making finer-grained distinctions and comparisons than those in earlier studies.

The novel results from these analyses suggest that breadth in knowledge sourcing benefits both service and manufacturing innovation. In contrast, breadth in terms of innovation objectives may even be detrimental to service innovation, whereas such strategies are positively associated with manufacturing innovation. It is hypothesized that accumulation of capabilities to effectively manage multiple objectives requires firms to set up a regularly operating R&D function, and in that way institutionalizing R&D processes, which fewer service firms traditionally do. Indeed, regular R&D activity appears to complement breadth in innovation objectives.

Regular R&D by service firms can thus be interpreted to facilitate benefitting from other, more complex, innovation strategies. This may reflect the relatively recent engagement of many service firms, particularly in infrastructural network industries, in systematic R&D activities. Moreover, contrary to received wisdom, regularly performed R&D plays an important role in innovation of the set of service industries included in our sample. R&D investments are found to be statistically and economically significant determinants of innovation for both service and manufacturing firms. Whereas it is still possible that service R&D work is organized differently from that in manufacturing, these results should help lay to rest the arguments about service innovation not requiring substantial investments in research and development work. However, the content of that work is likely to vary across economic sectors.

## 2. HOW IS SERVICE INNOVATION DIFFERENT? REVIEW OF EARLIER FINDINGS

To better understand the implications of service innovation for economic dynamism, it is useful to start by asking whether innovation in service activities is different from that in manufacturing activities. There are various answers to this question in the literature. Some scholars highlight the unique characteristics of services (Gallouj, 1997; Miles, 1994; Miles and Boden, 2000) and argue that the conceptual models of innovation originally developed for manufacturing industries do not apply in the service sector. Others (Evangelista, 2000; Leiponen and Drejer, 2007; Tether, 2005) using broad-based innovation surveys do not find very dramatic differences between the two sectors. Generally speaking, European innovation surveys suggest that there are greater differences within each sector than there are between the two sectors. In particular, and against expectations of some observers, many service firms are very innovative and invest highly in R&D. These “high-tech” services appear to innovate largely in the same ways high-tech manufacturing firms do (Tether and Massini, 2007).

The fundamental distinction between services and manufacturing is that most services are intangible and often co-produced with clients (Miles et al., 1995; Gallouj and Weinstein, 1997). These characteristics arguably influence the organization of service development activities. Sundbo (1997) and Miles (2007) suggested that service development projects are typically carried out by informal ad hoc committees or project teams rather than permanent R&D units. In interviews with knowledge-intensive business service (KIBS) executives, Leiponen (2001) found that some KIBS firms explicitly resist the formation of a dedicated new service development unit, because they find that it is important that employees engaged in innovation activities also interact directly with clients. Here, perhaps the co-production aspect comes into play. KIBS managers may feel that cross-functional teams cannot replace direct contact between clients and employees active in new service development.

Leiponen's results elsewhere (2005) also align with the proposition that business service innovation is often ad hoc in nature. R&D investments or permanent R&D units are not very strongly statistically associated with the introduction of new services. In the manufacturing sector, in contrast, R&D investments are very closely correlated with measures of innovation output. As relevant capabilities in business services reside to a large degree in individuals and teams as opposed to equipment or blueprints, in-house training has been argued to compensate for formal R&D activities in some business service firms (Leiponen, 2000). However, all of the cited studies examine the R&D – innovation relationship in cross-sectional and contemporaneous empirical models. They do not account for potential lags in the effects of R&D on commercialized innovations.

Additional differences between the two sectors include the sources of knowledge for innovation and the use of intellectual property rights to protect the returns on investments in innovation. For example, based on the European CIS data, Arundel et al. (2007) document that universities and research institutes are on average less valued as sources of information or as collaboration partners for service innovators relative to manufacturing innovators. Other CIS studies also have documented that service firms tend to rely more than manufacturing firms on consulting companies as sources of inputs for innovation (Tether and Tajar, 2008a).

The disembodied nature of many service processes also has implications for the protection of service innovations. Both Arundel et al. (2007) and Tether and Massini (2007) find that service innovators utilize formal intellectual property rights much less intensively than goods innovators do. Patenting service inventions is often difficult, because most new business processes are not patentable, although there are exceptions. Outside of software production copyrights also have fewer applications. The intriguing result by Tether and Massini (2007) is that service firms also use informal forms of protection such as secrecy or lead time less frequently than do manufacturing firms. Nevertheless, as one would expect, service firms tend to rely relatively more on confidentiality agreements, lead time, trademarks, and secrecy than on patents. Patents are the second most important method of protection for manufacturing firms and only the sixth most important one for services (Tether & Massini, 2007: 164).

In summary, recent studies suggest that many service firms are innovative, but they are relatively more likely than manufacturing firms to make non-technological innovations that are disembodied, organizational, and market-oriented. Their innovation processes are also more likely to be based on individuals' skills, professional knowledge and cooperation rather than R&D (Howells & Tether 2004; Tether, 2005).

## 3. HYPOTHESES ON THE RECOMBINATION OF KNOWLEDGE IN SERVICES

Considering that above differences have been identified, in what ways have processes of service and manufacturing innovation been found to be similar? In the Schumpeterian literature, innovation is conceptualized as a process of combination—of ideas, technologies, or capabilities (e.g., Schumpeter, 1942; Fleming & Sorenson, 2001; Mowery, Oxley, & Silverman, 1996). One can argue that, fundamentally, innovation activities in both services and manufacturing are about creating or sourcing relevant knowledge and combining it in new and valuable ways. Although manufacturing R&D typically involves interaction with tools and equipment, it is still primarily a "people" process, as is much of service innovation, whereby individuals develop models, concepts, and prototypes and interact with others to generate new knowledge and insights. This argument is supported by the fact that the bulk of manufacturing R&D expenditures involves salaries rather than tools, equipment or software (55% of expenditures in the R&D survey sample of Finnish manufacturing firms used here).

External sources of information have been found to be essential for any kind of innovation (e.g., Rothwell et al. 1974; Katila and Ahuja, 2002; Laursen and Salter, 2006) and to vary across different types of firms and industries. For example, Pavitt's taxonomy (1984) of innovation in different industries had patterns of information sourcing as one of the fundamental distinctions between sectors. Pavitt also characterized the different sectors in terms of their broad innovation objectives: creation of new products or new markets vs. process efficiency. Knowledge sources and innovation objectives are thus central elements of innovation strategy for both service and manufacturing firms.

Directly comparing the knowledge-sourcing patterns of samples of service and manufacturing industries, the Finnish CIS dataset indicates that firms in both manufacturing and service industries value customers as the most important source of information and ideas for innovation, followed by suppliers of equipment, technology and software, competitors, and consulting firms.

More generally, when comparing the CIS responses of service firms and manufacturing firms, apart from the aforementioned specific differences, the two sectors look fundamentally alike, not distinct. This was statistically documented in factor and cluster analyses by Leiponen and Drejer (2007). When Finnish and Danish firms were clustered based on their scores in a factor analysis of innovation activities, knowledge sources, and objectives for innovation, first, similar factors were found in services and manufacturing when the analyses were carried out separately for the two sectors, and second, when the analyses were carried out for the combined sample, service firms were found in all clusters alongside manufacturing firms and were not found to be particularly likely to cluster together. The differences found were a matter of degree: relatively fewer service firms were found in the "scale and science based" cluster dominated by large firms that source information from and collaborate with universities and use formal intellectual property rights, whereas relatively more service firms were found in the "market driven" cluster where they source information from clients with the objective of opening new markets and extending old ones. However, there is little evidence that the patterns of sourcing external knowledge or combining innovation objectives are fundamentally different for service and manufacturing firms.

The process of knowledge combination can be viewed from the perspective of breadth in innovative search strategies (Katila and Ahuja, 2002; Leiponen and Helfat, 2010). Breadth in innovation approach can be defined as strategies that enable accessing many different types of information sources or simultaneously pursuing multiple different innovation objectives. A few reasons have been discussed in the prior literature for why breadth in innovation strategies may be associated with innovation success. First, by engaging in multiple innovation experiments, firms increase the probability that at least one of them will succeed (cf. Evenson & Kislev, 1976; Nelson, 1961). In our survey dataset, we interpret the distinct innovation objectives to represent parallel approaches, projects, or paths to innovate. Parallel sources of information might also be useful from this "sampling" perspective: when firms tap into information from multiple external sources, the probability that at least one source provides information useful for innovation increases. Additionally, the diversity of information available to a firm might increase the likelihood that novel combinations are made.

To our knowledge, the implications of breadth in innovation strategies have previously been explicitly studied only in the manufacturing context. Although the specific sources of information or innovation objectives may vary between the two main sectors, prior studies have not suggested specific reasons to expect that service and manufacturing firms benefit qualitatively differently from their combination—the breadth of sources or objectives. Hence we hypothesize that breadth in innovation strategies is associated with innovation success in both service and manufacturing firms:

*H1a: Breadth in terms of knowledge sourcing and innovation objectives is positively associated with innovation success of both service and manufacturing firms.*

Earlier studies have suggested that as in-house R&D activities play a lesser role in service innovation, firms in service industries engage in a highly interactive pattern of innovation with their environments (e.g., Tether, 2005; Leiponen, 2005). Hence, breadth in terms of knowledge sourcing might be even more important for service firms than for manufacturing firms. Of course, breadth is costly, and, theoretically, firms should increase breadth only until the marginal benefit equals marginal cost. However, in practice, this optimal point may be difficult to identify or achieve, which enables the estimation of the effects of breadth.

The benefits of breadth may also depend on firms' R&D capabilities. Managing complex R&D activities including multiple R&D objectives and knowledge sources requires managerial experience and organizational processes. Mowery (1983, 1995) has investigated the historical process of institutionalization of the in-house R&D function, and the subsequent importance of industrial R&D laboratories in the United States. His research suggests that in-house laboratories greatly facilitated the accumulation, recombination, and sharing of knowledge within American corporations. Thus, institutionalized R&D may facilitate accumulating capabilities to manage multiple knowledge sources and objectives. Similarly, a dedicated alliance function has been found to facilitate alliance management. Kale et al. (2002) found that an institutionalized alliance function may act as a focal point for learning and leveraging lessons from previous alliances. A dedicated alliance function can also enhance the accumulation of tacit knowledge and facilitate its sharing through training programs or internal networks of alliance managers; it can enhance the legitimacy required to access and coordinate internal resources; and it may motivate the creation of appropriate metrics and the systematic measurement of alliance performance.

These above insights suggest that a dedicated R&D function may facilitate and enhance the management of R&D. An in-house R&D unit may support accumulation and sharing of knowledge to manage R&D projects; creation of legitimacy around resource mobilization for R&D; and better performance assessment to allocate R&D resources more efficiently. These aspects of R&D management are likely to be particularly relevant for complex innovation strategies such as breadth in knowledge sourcing or innovation objectives:

*H2a: Institutionalized R&D activities positively moderate the effect of breadth in innovation strategies.*

Recent research has argued that service innovation is less dependent on, or perhaps independent of, R&D activities, compared with manufacturing innovation. For example, Hipp and Grupp (2005: 532) conclude that the importance of R&D inputs in services is "uncertain" (p. 532) and Cainelli et al. (2006) suggest that R&D "is not at all appropriate" as an indicator for service firms' innovation activity (p. 436). To the degree that regular R&D plays a weaker role in service firms, as has been argued in earlier studies, we expect to find that breadth in innovation is less beneficial for service firms than for manufacturing firms. This qualifies the earlier hypothesis 1a about the benefits of broad innovation strategies:

*H1b: Service firms benefit less than manufacturing firms from breadth in innovation strategies.*

The different role of R&D in service firms may also originate from services "industrializing", adopting formal R&D practices and "overcoming their non-industrial heritage" (Miles, 2007: 259). Recent evidence suggests that the service sector share of total national business expenditures in R&D (BERD) is growing rapidly. According to Miles (2006, 2007), the growth of BERD was substantially higher in services than in manufacturing in both the European Union and the United States over the period 1987-1999. In the whole OECD area, services' share in BERD has increased from around 5% to around 15% between 1980 and 2001 (BIS, 2001). Furthermore, in the United States, one of the most advanced service economies, the share of service industries in BERD grew from 6 percent to 29 percent between 1984 and 2004 (NSF, 2004)—a substantially higher share compared with 13 percent in the EU (EC 2006). Although software-related services represent a large share in the total service sector R&D (about 50% in the United States in 2004), the growth of R&D investments has also been substantial in other service industries, notably in telecommunications, finance, scientific R&D and other technical services.

Although a part of the observed service R&D growth, and the US-EU differential, is suspected to be related to improvements in service R&D measurement, other reasons may include globalization, deregulation, and overall stricter competition policies (Miles, 2007), as well as enhanced innovation opportunities due to evolving information and communication technologies that force many service industries to become more competitive through continuous innovation and improvement.

Because of the strong market trend toward increasing engagement of service firms in regular R&D, the role of R&D is expected to have become more significant in service innovation. Regular R&D engagement is expected to particularly help service firms to engage in more complex innovation strategies, such as broad knowledge sourcing or innovation objectives. Hence, the moderation effect hypothesized earlier is expected to be particularly strong for service firms:

*H2b: Institutionalized R&D activities by service firms positively moderate the effect of broad innovation strategies.*

In the following sections we carry out empirical analyses that compare firms in service and manufacturing industries, the starting point being that service innovation does not necessarily depend on a process that is fundamentally or conceptually different from the manufacturing one. However, one might erroneously perceive service innovation to be different if cumulative, regularly performed R&D moderates the effects of innovation strategies, and if service firms are less likely to engage in this type of regular R&D.

## 4. DATA

The empirical analyses to follow are based on a cross-sectional dataset of Finnish innovation-active service and manufacturing firms. Finland has a small open economy that is tightly integrated with other European economies through the country's membership in the European Union (EU).

Compared to other OECD countries, the most unique features of the Finnish innovation system are the extent and high quality of the public education system (e.g., OECD, 2006), high investments in R&D and their concentration in electronics, particularly in telecommunication equipment, and the large number of researchers per total employment (OECD, 2008). Moreover, the government plays a relatively active role in funding R&D. Through the National Technology Agency, TEKES, the Finnish government funds research related to national technology programs by firms, universities, and non-profit research institutes, and often this funding is more easily obtained for some type of collaborative research projects to promote spillovers in the economy. Indeed, R&D cooperation is more common in Finland than in most other OECD countries. Nevertheless, the share of cooperating firms in Finland is about the same as in Denmark (Leiponen & Drejer, 2007) and only slightly higher than that in the United Kingdom (Tether, 2002). Overall, there is little reason to expect the relationship between firms' innovation output and their innovation strategies to substantially differ between Finland and other EU countries. For example, in a comparative study of the Finnish and Danish industries (Leiponen and Drejer, 2007), the patterns of innovation were very similar in the two countries.

The second Finnish Community Innovation Survey (CIS2) was implemented in 1997 and its questions concern firms' innovation investments, outputs, and activities in the preceding three years (1994-1996). All of our explanatory variables originate from this survey. Statistics Finland, the national statistical office, also collects information about R&D investments and innovation output in the years when CIS is not carried out. This R&D survey targets R&D-performing firms in all manufacturing industries and in some service industries. Our dependent variables are obtained from the R&D survey concerning innovation in 1996-1998. When the Finnish 1994-96 CIS2 dataset is combined with the 1996-98 R&D survey, 533 observations in total are retained when firms with some innovation activity are included (firms with any innovation projects, investments, collaboration, or innovation output). Of these, 121 are service firms in nine different two-digit service industries. Most importantly, all personal services are excluded. Table 1 displays the industry distribution in this combined sample.

TABLE 1 ABOUT HERE

Compared to the original, representative CIS2 sample of innovation-active firms in the surveyed service industries (204 firms in total), the sample utilized here contains fewer observations (121) because of the merging of the CIS data with the R&D survey data. Nevertheless, the industry distribution here largely conforms to the original one except that the current sample contains relatively fewer wholesale trade firms (NACE 51: 17% of the service sample) than the original representative CIS sample (24%) and relatively more computer service providers (NACE 72: 20% of the service sample) than the original sample (18%). Moreover, firms that were found in both data sources and thus were included in the current study are larger (463 employees vs. 302 employees) and more

R&D intensive (R&D investments 4.4% of sales vs. 3.5%). With respect to export intensity, frequency of service innovation, training investments, patenting, and innovative collaboration, the differences between the current sample and the representative CIS sample are small and not statistically significant. The current sample of service firms used here is thus slightly biased toward larger and more R&D intensive firms. For the manufacturing sector, the combined sample of CIS2 and the subsequent R&D survey is very close to the representative CIS2 sample, but nevertheless, manufacturing firms in the merged sample are also slightly larger, more R&D intensive, and export-oriented.

Descriptive statistics for the combined sample are provided in table 2. In general, the sampled firms are quite innovative—almost 14 percent of these firms' sales were derived from new products or services introduced within the previous three years. 76 percent of the firms innovated in the previous three-year period, 1994-96.

The CIS questionnaire is based on Frascati manual's definition of R&D and asks respondents to report expenditures related to "systematic activities, the purpose of which is to increase knowledge or to develop new applications based on existing capabilities." The questionnaire goes on to define the development of prototypes as a central element in R&D and to include software development when software is significantly improved or when software development is part of an R&D project. The Frascati definition of R&D has been criticized by service scholars as being too focused on technical artifacts (Howells, 2007) and not include social science research (Miles, 2007), which might bias the measurement of innovation investments of service firms.

Regarding types of service innovation projects that the data may capture, the project descriptions available in the Finnish CIS dataset indicate that many service R&D

projects include adoption of new information and communication technologies in service development and delivery. For example, these projects included the adoption of 3D design technologies and numerical simulation methods in machine and process engineering; advanced data management capabilities and new control systems in fixed-line telephone networks; and development of online storefronts and associated digital capabilities. However, other types of service process or product development were also reported, for example, new types of filter membranes for waste water treatment; controllable vacuum systems for paper machine engineering; new financial concepts for real-estate markets; and new measurement instruments for wood process engineering.

To proxy for the institutionalization of R&D, we utilize a survey question that asks whether R&D activities in the firm are continuous. We call this binary variable regular R&D, and find that almost 60% of the sampled innovation-active firms carry out regular R&D (table 2). Whereas this is not a perfect measure for institutionalization of R&D, it should be highly correlated with the concept of interest. First, institutionalized R&D is very highly likely to be reported as "continuous." Second, any continuity in R&D activity should support the accumulation of relevant managerial capabilities.

TABLE 2

We divide the combined sample into four different groups. Services are split into network services (electricity, gas & water; transportation; telecommunications) and knowledge-intensive business services (computer services and technical services). There are 44 firms in the business service group, and 76 firms in the network service group. The manufacturing sample is split into discrete- and complex-technology industries, following

Cohen et al. (2000). Discrete-technology industries include chemical, food, paper, and metals (222 firms), and the group of complex-technology industries consists of machines and equipment, electronics, and transportation equipment (192 firms).

TABLE 3

When we compare across the four subsectors (table 3), we find that services as a whole are rarely outliers; there is substantial variation within each main sector. For example, business services have the most highly trained technical staff of all four groups, and network service firms have the least highly trained staff. Similarly, business services are the most R&D intensive group, while network services are about as R&D intensive as discrete-technology manufacturing. Network services are also the least export intensive and the least innovative group. Nevertheless, with their emphasis on process efficiency, network services are in many ways similar to the manufacturing sector in terms of their objectives for innovation.

TABLE 4

In accordance with other CIS studies, an observed difference between the two sectors is in terms of reliance on consulting firms and universities as sources of information for innovation, corroborating findings from earlier studies (table 4). Both business and network service firms rate the importance of information from consultancies as higher than do their counterparts in the manufacturing sector. Network service firms also source information from and collaborate less often with universities than do manufacturing firms. Service firms also tend to source information for innovation from databases and the Internet, while manufacturing firms are relatively more likely to use trade fairs, exhibitions, and patents as sources of external information.

Patents are not very useful as a source of knowledge for these service firms. However, although this might suggest that appropriation of returns to innovation is a problem for service innovators, according to the knowledge sourcing indicators in table 4, service firms obtain less knowledge for innovation from their competitors than either of the manufacturing subsectors. Horizontal knowledge flows thus appear to be less prominent or less useful in these service industries than in manufacturing. In contrast, almost all firms in all subsectors agree that customers are an important source of knowledge for innovation. In terms of breadth of knowledge sourcing, a key variable in this study, service firms overall report slightly fewer different types of important knowledge sources than do manufacturing firms, but the difference is not statistically significant.

Innovation objectives are another aspect in which we will assess the breadth of a firm's innovation strategy. The Finnish CIS2 questionnaire is exceptional in Europe in that it asked about the importance of ten different objectives for (rather than effects of) innovation activity: replacing outdated products; improving product quality; expanding product assortment; entering new markets or increasing market share; increasing flexibility of production; reducing labor costs; reducing use of materials; reducing use of energy; fulfilling government regulations or standards; and mitigating environmental damage. This is the main reason for using this particular (older) survey wave – subsequent CIS waves asked about the effects of innovation rather than objectives for innovation, as do surveys of all other European countries, to our knowledge. Here, network services are not very different from manufacturing firms in most aspects (table 4). Business services, in contrast, are less often than the other groups focused on production flexibility, materials use, or energy consumption. This makes sense considering business services typically do not involve physical transformation or transportation of raw materials. Consequently, business services also engage in the least broad set of innovation objectives. More generally, there are few noticeable differences between the subsectors in terms of breadth of innovation objectives.

## 5. REGRESSION ANALYSES

In this section we use the Finnish survey data to test the hypotheses developed in section three using simple tobit regression analyses. We seek to explain the natural logarithm of sales revenue in 1998 derived from innovative products or services that were introduced in the preceding three-year period.

Our control variables, all dating from 1996, include firm size as the natural logarithm of employees to control for scale effects in innovation; business group (whether the firm has a domestic or a foreign parent) to control for organization structure and possible knowledge flows from the parent; and export intensity to control for incentives for innovation from international competition. Additionally, two-digit industry dummies are included. I also include a lagged binary indicator of any product or service innovations in 1994-1996 (from CIS2). This controls for unobserved innovation capabilities that in the previous period led to commercialized innovations.[1]

[1] Least-squares regressions with lagged dependent variables produce consistent estimates if the error terms are uncorrelated over time (Greene, 1997). Under autocorrelation, linear models using a lagged dependent variable produce downward-biased coefficient estimates of other explanatory variables. Nevertheless, Keele and and Kelly (2005) find that if the model truly is dynamic, it is better to include a lagged dependent variable than to omit it—more severe biases are caused by omitting it. Standard errors may also be deflated in lagged dependent variable models with autocorrelation. For our sample, when the models are estimated without the lagged dependent variable, the results are substantively the same as those reported here. However, the standard errors are almost identical in models with and without the lagged innovation variable. We are thus convinced that overconfidence is not driving our results. However, the coefficient estimates presented here may be viewed as a lower bound for the economic importance of our key explanatory variables.

However, a lagged dependent variable will not remove all potential biases resulting from endogeneity. Coefficient estimates of innovation strategies (R&D, knowledge sourcing, innovation objectives) are likely to be biased, and potentially upward, because unobserved factors not captured by the lagged innovation variable may make firms both adopt these types of strategies and be successful in commercializing innovations. Hence, the estimation results should be interpreted as evidence that certain innovation strategies are correlated with certain types of outcomes, whereas causality of such relationships cannot be ascertained. In all regressions we fit tobit maximum likelihood models using Stata 9.2.

The explanatory variables of interest in the first set of results in table 5 include the knowledge investment variables measured as natural logarithms of R&D and training expenditures. To compare the importance of R&D and training investments in service and manufacturing innovation, we estimate separate coefficients for the two main industrial sectors. Training is included as earlier research on knowledge-intensive business services suggested that in-house training may compensate for R&D activities in smaller service firms that rely on employees' skills to a large extent. In-house training may provide opportunities for new product or service brainstorming and research, and once product or service development is under way, training can play an important role in adopting the associated new processes, procedures, and technologies internally.

TABLE 5

In contrast to much of the earlier research, R&D investments are found to significantly explain sales resulting from service innovation. In fact, the results obtained here suggest that service firms benefit more from their innovation investments in terms of innovative sales than do manufacturing firms. The coefficients, which in a tobit model equal the marginal effect for firms with strictly positive innovation sales, for regular R&D and for log of R&D investments are systematically larger and more significant for service firms than for manufacturing firms, with few exceptions. Meanwhile, training expenditures are also important for innovators in both sectors, and the difference between the sectors is not significant.

The first specification examines the effects of R&D and training investment levels only, whereas the last specification includes the dummy variable for regular R&D, again, estimated separately for services and manufacturing firms. The latter variable captures most explanatory power of R&D activity. This result points to the cumulative nature of the capabilities, both managerial and technical, underlying R&D activity. Continuity in R&D effort facilitates creation of more valuable product or service innovations and is more significant for both sectors than investment levels *per se*.

We thus obtain clear evidence that both R&D investments and training related to innovation matter for both service and manufacturing innovation performance. A possible reason why some earlier studies have failed to find the connection between R&D and service innovation outcomes is that most studies have used simultaneously measured dependent and explanatory variables. However, time lags can be important, particularly for smaller service firms. For example, in the current sample, there is no concurrent connection between R&D investments and service innovation output. The time lag of two years used here is thus empirically important.

Regarding the control variables used in the first regression models, coefficients are mostly as expected and size is positively and significantly related to innovative sales, whereas business group and export intensity variables are insignificant, although business group structure has an unexpected negative and marginally significant effect on sales of new-to-the-market products or services. A very strong positive effect is obtained for lagged product or service innovation.

The next set of analyses, reported in table 6, compares the two sectors in terms of their benefits from breadth in innovation strategies. Here we examine breadth with respect to external information sourcing and objectives for innovation, again estimating separate coefficients for service firms, corresponding to hypotheses 1a and 1b. The variables of interest are the sum of important sources of knowledge and the sum of important innovation objectives. In specification 1, we find that breadth in knowledge sources is again positively and significantly associated with sales of innovative products. When the coefficient is estimated separately for service and manufacturing subsectors in specification 2, it appears that discrete-technology manufacturing and KIBS firms benefit the most from breadth in knowledge sourcing, although the KIBS coefficient is only weakly significant (p=0.08). The coefficients for complex-technology manufacturing and network services are also positive, but not statistically significant. Nevertheless, the evidence suggests that there are no drastic differences among the four subsectors in terms of benefitting from breadth in knowledge sourcing, although the benefits for complex manufacturing and network service firms may vary widely, leading to low statistical significance.

TABLE 6

Specifications 3 and 4 carry out similar analyses for breadth in terms of innovation objectives. The coefficient for the sum of important objectives in specification 3 is positive but not quite statistically significant. It turns out that benefits from breadth in innovation objectives are more widely variable across the four subsectors. In specification 4 we estimate again separate coefficients for each subsector. The largest coefficients are obtained again for discrete-technology manufacturing and KIBS, although both coefficients are only weakly significant. In contrast, the coefficient of innovation objectives for network services is strongly negative. If these coefficients are separately estimated for even more fine-grained manufacturing subsectors (splitting discrete-technology industry group into food & chemicals and metals, and complex-technology group into machines, electronics, and other manufacturing), the coefficients for breadth in innovation objectives vary considerably, but remain positive for all subsectors except network services.

Taken together, these results suggest that whereas breadth in knowledge sourcing is universally beneficial for product or service innovation, benefits of breadth in innovation objectives are more variable and perhaps difficult to achieve. One possible explanation for the diverse results on innovation objectives is that managing parallel objectives requires relatively sophisticated R&D project management capabilities. With an R&D organization that is often ad hoc in nature, service firms may not have as solid R&D management capabilities as manufacturing firms do.

Per hypotheses 2a and 2b, testing the idea of R&D capabilities moderating the effect of breadth in innovation objectives, a coefficient for objectives and a coefficient for services interacted with objectives are estimated separately for firms that had regular R&D activities (table 7). These results are consistent with the hypotheses that R&D management capability is a prerequisite for benefiting from broad innovation objectives—particularly for service firms. Although breadth in innovation objectives is detrimental to innovation by service firms in general (the interaction term of service and sum of objectives is negative), regular R&D more than compensates for this negative effect: the three-way interaction term of regular R&D, breadth in objectives, and service dummy is positive and significant, and greater than the negative coefficient for the interaction between service dummy and the sum of important objectives. This suggests that service firms with regular R&D may benefit from breadth in objectives and not just mitigate the harm that is caused by broad strategies. The last specification in table 7 shows that the negative effect of broad innovation objectives obtained in table 6 for network service firms may be positive for network service firms that have regular R&D activities. Having an institutionalized R&D function, or at least continuous R&D activities, is thus a significant distinguishing factor for network service firms that may benefit from broader objectives relative to those that do not.

TABLE 7

## CONCLUSIONS

The novel results of this paper suggest that breadth in innovative search strategies that have been highlighted as essential for manufacturing firms may also be very beneficial for service innovators, but this may depend on the firms' existing R&D capabilities. Breadth of innovative search through external sources of knowledge and innovation objectives have been emphasized in prior literature on manufacturing innovators as essential strategies toward innovation success. However, these strategies have not previously been explicitly analyzed in the context of service firms.

In this study, both service firms and manufacturing firms are found to benefit from the diversity of information flows afforded by the breadth of external knowledge sources. In contrast, the effects of breadth in terms of innovation objectives appear to be different for service innovators relative to manufacturing innovators. Breadth in innovation objectives is an economically and statistically significant positive factor behind innovation in many manufacturing industries. However, it does not significantly explain service innovation. These results are further explored with the moderating factor of regular R&D activities. We find a significant positive interaction effect of regular R&D and the benefits of breadth in objectives for service firms. In other words, service firms that carry out R&D on a regular basis appear to be better able to benefit from breadth in innovation objectives. This is interpreted with reference to innovation management capabilities. Firms with regular R&D activities are more likely to have accumulated capabilities to manage parallel innovation objectives.

Our empirical analyses also imply that R&D activities are statistically and economically very important for service innovation in the network and business service industries covered by the Finnish CIS2 sample, and that the estimated effect of service R&D is no less important than that of manufacturing R&D. Considering the thrust of the extant research into the determinants of service innovation, this result may be helpful in moving the debate in a direction that acknowledges the relevance of service R&D. Most recent studies on service innovation continue to understate the contributions of R&D investments and activities, even though the global evidence suggests services as a group make considerable investments and carry out innovation projects in a continuous and systematic fashion. However, there are few, if any, studies that explicitly compare manufacturing and service firms in this regard.

The results obtained here should not be interpreted to mean that service R&D does not need to be complemented with a number of other investments and assets, such as skills, training, marketing, design, and organizational change, or that successful service innovation does not require close communication with customers. However, it is argued here that innovation is hard work, independent of the sector in which it is performed, and professional management of a regular, even institutionalized R&D function can facilitate accumulation of technical knowledge (including both service and manufacturing technologies) and R&D management capabilities. Although "ad hoc" innovation may be prevalent in certain service or manufacturing industries or firms, it is not necessarily a successful long-term strategy in a competitive and deregulated economy.

The findings that R&D has stronger coefficients for service firms than for manufacturing firms and that regular R&D moderates the effects of other service innovation strategies suggest that the organization of service innovation may be suboptimal in some firms. In the service industry sample used here, there appear to be firms that engage in broad innovative search strategies without the capabilities to effectively manage them. Evidence suggests that formal R&D in the service sector has been growing rapidly since the early 1980s, and some firms in the sector may thus be catching up in terms of their R&D investments and organization.

Many of the extant studies of service innovation discuss the fact that CIS questionnaires were developed with manufacturing innovation in mind and might miss some important elements of service innovation. One aspect missing from the survey dataset used here is organizational innovation, which Tether (2005) found to be relevant for service firms. Second, as discussed by Miles (2007), current survey questionnaires based on the Frascati manual may still underestimate the investments service (and manufacturing) firms make in social science research. The measurement of service-related R&D thus still may suffer from conceptual deficiencies. Moreover, regarding the four different subsamples examined here, estimation models were able to explain certain aspects of innovation better in the more traditional industries of discrete manufacturing than in complex manufacturing or in knowledge-intensive business services. We suggest that the field of innovation studies, where many of the key findings originate from data on pharmaceuticals and information technology (two science-based industries), has too few nuanced analyses that convincingly assess whether the findings from single-industry studies actually generalize to a broader set of industries, and when that might be the case.

This empirical study used Finnish CIS2 data combined with subsequent R&D survey data to analyze the differences in the determinants of innovation between service and manufacturing firms. The descriptive analyses of the service and manufacturing samples are largely aligned with earlier survey studies, most of which use CIS datasets for other European countries. This increases our confidence in the generalizability of the results obtained here beyond the small sample from the small Finnish economy. The empirical analyses utilized a cross-sectional research design where explanatory variables were lagged by two years and included an indicator of lagged innovation success to account for the unobserved propensity to innovate.

Although this approach reduces the problems of simultaneity and unobserved heterogeneity that have plagued most of extant research, there may remain issues of endogeneity not captured by the lagged innovation indicator. It is thus possible that the coefficient estimates are biased by unobserved factors that influence both innovation strategies and innovation outcomes. For example, economic or technological changes that enhance the benefits from a specific external knowledge source and provide new innovation opportunities might make the coefficient of breadth in knowledge sourcing upward biased. It would appear as if breadth in knowledge sourcing is very beneficial for innovation, even though the true causal effect runs from the environmental changes to innovation outcomes. At the same time, the lagged innovation variable may bias the coefficients of other explanatory variables down. In the future, when panel datasets of CIS surveys accumulate, research designs utilizing longitudinal datasets or natural experiments created by policy changes might be able to mitigate these types of estimation challenges. Moreover, these hypotheses should be tested using datasets that include service industries such as financial services and trade that were excluded from the Finnish CIS2 survey.

To conclude, we find that, in the light of the Finnish CIS data, R&D activities and breadth in knowledge sourcing strategies play similar and important roles in both service innovation and manufacturing innovation. Firms in service industries benefit from broad sourcing of external knowledge and make substantial investments in R&D. Earlier literature seems to have underestimated the importance of R&D in many service innovation projects. In the samples and factors examined here, determinants of service innovation are thus in many ways similar to those of manufacturing innovation. However, breadth in innovation objectives appears to have only weakly positive or even negative effects on the sales of innovative services. More detailed analyses find that in-house managerial capabilities built through regularly-performed R&D activities may enable service firms to benefit from breadth in objectives, too.

For managers of service innovation, these results suggest that greater breadth in terms of external knowledge sourcing is likely to enhance innovative outcomes, and that the development of more systematic and professional R&D management capabilities may generate returns both directly and indirectly in terms of being able to benefit from more complex innovation strategies such as breadth in innovation objectives. For policy-makers, the study emphasizes the importance and effects of R&D in the service sector. Measurement efforts, tax incentives and other subsidy policies, and national technology programs should all recognize the contributions of the service sector R&D to economic dynamism. Finally, for innovation scholars, the results here suggest service innovation processes are perhaps slightly less “peculiar” than has been previously argued and might benefit from innovation strategies and capabilities that have been found valuable in the manufacturing sector. Future research opportunities include more detailed assessment in the service sector of the effects of other innovation strategies prevalent in manufacturing such as strategic alliances and other cooperative forms of innovation.

## REFERENCES


Abernathy W.J. and J.M. Utterback (1978), 'Patterns of industrial innovation,' *Technology Review*, (June/July), 40-47.

Arundel A., M. Kanerva, A.v. Cruysen and H. Hollanders (2007), 'Innovation statistics for the European service sector,' Research report, UNU-MERIT: Maastricht, The Netherlands.

Barras R. (1986), 'Towards a theory of innovation in services,' *Research Policy*, **15**, 161-173.

Barras R. (1990), 'Interactive innovation in financial and business services: The vanguard of the service revolution,' *Research Policy*, **19**, 215-237.

Baumol W.J. (1967), 'Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis,' *American Economic Review*, **57**(3), 415-426.

BIS. 2001 (2011), *Science Base -- Service Links*. Background paper. CST Secretariat, UK Department of Business, Innovation and Skills. Retrieved from http://www.bis.gov.uk/assets/bispartners/cst/docs/files/whats-new/01-1783-science-base-services-links.pdf on June 13, 2011.

Chesbrough, H. (2003), *Open Innovation: The New Imperative for Creating and Profiting from Knowledge*. Harvard Business School Press: Cambridge, MA.

Christensen J.L. and I. Drejer (2007), 'Blurring boundaries between manufacturing and services,' Report for the ServINNo project: Service Innovation in the Nordic Countries: Key Factors for Policy Design. Aalborg University: Aalborg, Denmark.

CIA (2009), The World Factbook:

Cohen, S. and J. Zysman (1987), *Manufacturing Matters*. Basic Books: New York, NY.

Cohen, W.M., R.R. Nelson and J.P. Walsh (2000), 'Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent (or not),' Working Paper 7552. NBER: Cambridge, MA.

Coombs R. and I. Miles (2000), 'Innovation, measurement and services: The new problematique,' in: S.J. Metcalfe & I. Miles (eds.), *Innovation Systems in the Service Sectors: Measurement and Case Study Analysis*. Kluwer: Boston, MA, 85-104.

Drejer I. (2004), 'Identifying innovation in surveys of services: A Schumpeterian perspective,' *Research Policy*, **33**, 551–562.

Evangelista R. (2000), 'Sectoral patterns of technological change in services,' *Economics of Innovation and New Technology*, **4**, 183-221.

Evangelista R. and M. Savona (2003), 'Innovation, employment, and skills in services: Firm and sectoral evidence,' *Structural Change and Economic Dynamics*, **14**, 449-474.

Evenson R.E. and Y. Kislev (1976), 'A stochastic model of applied research,' *Journal of Political Economy*, **84**, 265-282.

Fleming L. and O. Sorenson (2001), 'Technology as a Complex adaptive system: Evidence from patent data,' *Research Policy*, **30**, 1019-1039.

Gallouj F. and O. Weinstein (1997), 'Innovation in services,' *Research Policy*, **26**, 537-556.

Gallouj F. and M. Savona (2009), 'Innovation in services: A review of the debate and a research agenda,' *Journal of Evolutionary Economics,* **19**, 149-172.

Greene, WH. (1997), *Econometric Analysis.* Prentice-Hall: Upper Saddle River, NJ, 3rd ed.

Hipp, C. and H. Grupp (2005), 'Innovation in the service sector: The demand for service-specific innovation measurement concepts and typologies,' *Research Policy,* 34, 517-535.

Howells, J. (2007), 'Fostering innovation in services,' Report of the Expert Group on Innovation in Services, European Commission.

Howells, J. and B. Tether (2004), 'Innovation in services: Issues at stake and trends,' Inno Studies Programme (ENTR-C/2001), Commission of the European Communities, Brussels, Belgium.

Kale, P., J.H. Dyer and H. Singh (2002), Alliance capability, stock market response, and long-term alliance success: The role of the alliance function,' *Strategic Management Journal*, **23**, 747-767.

Katila, R. and G. Ahuja (2002), 'Something old, something new: A longitudinal study of search behavior and new product introduction,' *Academy of Management Journal*, **45**(6), 1183-1194.

Keele, L and N.J. Kelly (2005), *Dynamic Models for Dynamic Theories: The Ins and Outs of Lagged Dependent Variables*. Unpublished manuscript. Oxford University and University of North Carolina, Chapel Hill, NC.

Laursen, K. and A. Salter (2006), 'Open for innovation: The role of openness in explaining innovative performance among UK manufacturing firms.,' *Strategic Management Journal*, **27**(2), 131-150.

Leiponen, A. (2000), 'Innovation in services and manufacturing: A comparative study of Finnish industries,' ETLA B 165, ETLA: Helsinki, Finland.

Leiponen, A. (2001), 'Knowledge services in the innovation system,' B 185. ETLA: Helsinki, Finland.

Leiponen, A. (2005), 'Organization of knowledge and innovation: The case of Finnish business services,' *Industry and Innovation*, **12**(2), 185-203.

Leiponen, A. and I. Drejer (2007), 'What exactly are technological regimes?: Intra-industry heterogeneity in the organization of innovation activities,' *Research Policy*, **36**, 1221-1238.

Leiponen, A. and C.E. Helfat (2010), 'Innovation objectives, knowledge sources, and the benefits of breadth,' *Strategic Management Journal*, **31**(3), 224-236.

Miles, I. (1993), 'Services in the new industrial economy,' *Futures*, **25**, 653-672.

Miles, I. (1994), 'Innovation in Services,' In M. Dodgson and R. Rothwell (eds.), *The Handbook of Industrial Innovation*. Edward Elgar: Aldershot, UK, 243-256.

Miles, I. and M. Boden (2000), 'Introduction: Are services special?,' in I. Miles and M. Boden (eds.), *Services and the Knowledge-Based Economy*. Continuum: London, UK, 1-20.

Miles, I., N. Kastrinos, R. Bilderbeek and P.D. Hertog (1995), 'Knowledge-intensive business services: Users, carriers and sources of innovation,' European Innovation Monitoring System (EIMS) Report 15, European Innovation Monitoring System (EIMS).

Mowery, D.C. (1983), 'The relationship between the contractual and in-house forms of industrial research in American manufacturing, 1900-1940,' *Explorations in Economic History*, **20**, 351-374.
Mowery, D.C. (1995), 'The Boundaries of the U.S. Firm in R&D,' in N.R. Lamoreaux and D.M.G. Raff (eds.), *Coordination and Information: Historical Perspectives on the Organization of Enterprise*. University of Chicago Press of NBER: Chicago, IL.
Mowery, D.C. (2009), 'Plus ca change: Industrial R&D in the "third industrial revolution",' *Industrial and Corporate Change*, **18**(1), 1–50.
Mowery D.C., J.E. Oxley and B.S. Silverman (1996), 'Strategic alliances and interfirm knowledge transfer,' *Strategic Management Journal*, **17**, 77-91.
Nelson, R. R. (1961), 'Uncertainty, learning and the economics of parallel research and development efforts,' *Review of Economics and Statistics*, **43**, 351-64.
NSF (2004), 'National Science Foundation/Division of Science Resources Statistics,' Survey of Industrial Research and Development.
OECD (2005), 'Growth in services: Fostering employment, productivity, and innovation,' Report for the Meeting of the OECD Council at Ministerial Level.
OECD (2006), *Science Competencies for Tomorrow's World.* OECD Programme for International Student Assessment. Retrieved 6/11/2009 from www.pisa.oecd.org.
OECD (2008), *Science, Technology, and Industry Outlook*. Retrieved 6/11/2009 from www.oecd.org/sti/outlook, 116-117.
Pavitt K. (1984), Sectoral Patterns of Technical change: Towards a taxonomy and a theory,' *Research Policy*, **13**, 343-373.
Rosenkopf, L. and A. Nerkar (2001), 'Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry,' *Strategic Management Journal*, **22**(4), 287-306.
Rothwell, R., C. Freeman, A. Horlsey, V.T.P. Jervis, A. B. Robertson and J. Townsend (1974), 'SAPPHO Updated: Project SAPPHO Phase II,' *Research Policy*, **3**, 258-291.
Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*. Unwin: London, UK.
Sundbo, J. (1997), 'Management of innovation in services,' *Service Industries Journal*, **17**(3), 432-455.
Tether B. and S. Massini (2007), Services and the innovation infrastructure,' *Innovation in Services*, UK Department of Trade and Industry Occasional Paper No. 9: London, UK.
Tether, B.S. (2005), 'Do services innovate (differently)?: Insights from the European Innobarometer survey,' *Industry and Innovation*, **12**(2), 153-184.

**Table 1 Industry distribution**

| NACE | Industry | N | Share | Subsample group |
|---|---|---|---|---|
| 15-16 | Food, beverages and tobacco | 36 | 6.8% | Discrete manufacturing |
| 17-19 | Textiles, wearing apparel and leather | 19 | 3.6% | Discrete manufacturing |
| 20-22 | Wood, pulp, paper, printing and publishing | 53 | 9.9% | Discrete manufacturing |
| 23-25 | Petroleum, chemicals, rubber and plastic products | 60 | 11.3% | Discrete manufacturing |
| 26-28 | Metals, metallic and non-metallic min. products | 54 | 10.1% | Discrete manufacturing |
| 29 | Machinery and equipment n.e.c., | 83 | 15.6% | Complex manufacturing |
| 30-33 | Electrical and optical equipment | 77 | 14.4% | Complex manufacturing |
| 34-35 | Transportation equipment | 22 | 4.1% | Complex manufacturing |
| 36-37 | Manufacturing n.e.c. | 11 | 2.1% | NA |
| 40-41 | Electricity, gas and water supply | 15 | 2.8% | Network service |
| 51 | Wholesale trade and commission trade, except of motor vehicles and motorcycles | 20 | 3.8% | Network service |
| 60-62 | Land, water and air transport | 19 | 3.6% | Network service |
| 64.2 | Telecommunications | 23 | 4.3% | Network service |
| 72 | Computer and related activities | 21 | 3.9% | Knowledge-intensive business service |
| 74.2 | Architectural and engineering activities and related technical consultancy | 20 | 3.8% | Knowledge-intensive business service |
| | *Total* | *533* | *100.0%* | |

## Table 2 Descriptive statistics (N=533)

| Variable | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|
| % of sales from product/service innovations (1998) | 13.741 | 22.146 | 0 | 100 |
| Product innovations (1996) | 0.756 | 0.430 | 0 | 1 |
| Employees | 424.841 | 1566.977 | 1 | 24250 |
| Business group | 0.527 | 0.500 | 0 | 1 |
| Export share | 0.278 | 0.317 | 0 | 0.998 |
| Higher technical skills | 0.073 | 0.175 | 0 | 2.647 |
| Training expenditure/sales | 0.001 | 0.004 | 0 | 0.063 |
| R&D expenditure/sales | 0.036 | 0.097 | 0 | 1.184 |
| Regular R&D | 0.582 | 0.493 | 0 | 1 |
| Sum of important knowledge sources | 4.983 | 2.198 | 0 | 12 |
| Sum of important innovation objectives | 5.683 | 2.243 | 0 | 10 |

## Table 3 Means for service and manufacturing subsectors

| Variable | Business service | Network service | Complex manufacturing | Discrete manufacturing |
|---|---|---|---|---|
| % of sales from product innovations (1998) | 18.727 | 4.948 | 21.273 | 9.466 |
| Product innovations (1996) | 0.837 | 0.829 | 0.786 | 0.689 |
| Employees | 135.977 | 649.156 | 309.574 | 519.480 |
| Business group | 0.465 | 0.434 | 0.474 | 0.617 |
| Export share | 0.153 | 0.023 | 0.400 | 0.286 |
| Higher technical skills | 0.222 | 0.048 | 0.064 | 0.061 |
| Training expenditure/sales | 0.005 | 0.001 | 0.001 | 0.001 |
| R&D expenditure/sales | 0.092 | 0.017 | 0.058 | 0.014 |
| Regular R&D | 0.628 | 0.316 | 0.625 | 0.626 |
| Sum of important knowledge sources | 4.581 | 4.711 | 5.010 | 5.131 |
| Sum of important innovation objectives | 5.349 | 5.789 | 5.651 | 5.739 |

Note: Excluding 11 firms from the industry class 36-37 (manufacturing not included elsewhere).

## Table 4 Elements of innovation breadth for the subsamples

| Means | Business service | Network service | Complex manufacturing | Discrete manufacturing |
|---|---|---|---|---|
| **Knowledge sources (0/1):** | | | | |
| 1. Own firm | 0.932 | 0.792 | 0.918 | 0.843 |
| 2. Business group | 0.341 | 0.325 | 0.251 | 0.372 |
| 3. Competitors | 0.341 | 0.455 | 0.574 | 0.552 |
| 4. Customers | 0.886 | 0.740 | 0.902 | 0.798 |
| 5. Consulting firms | 0.250 | 0.273 | 0.153 | 0.166 |
| 6. Suppliers of equipment, materials, components, or software | 0.341 | 0.558 | 0.454 | 0.502 |
| 7. Universities | 0.341 | 0.221 | 0.383 | 0.381 |
| 8. Public or private non-profit research institutes | 0.205 | 0.130 | 0.213 | 0.291 |
| 9. Patents | 0.000 | 0.013 | 0.148 | 0.126 |
| 10. Conferences, scientific/trade publications | 0.250 | 0.506 | 0.393 | 0.462 |
| 11. Databases (e.g. Internet) | 0.295 | 0.338 | 0.153 | 0.117 |
| 12. Trade fairs, exhibitions | 0.295 | 0.299 | 0.481 | 0.498 |
| **Objectives (0/1):** | | | | |
| 1. Replace outdated products | 0.773 | 0.766 | 0.699 | 0.574 |
| 2. Improve product quality | 0.909 | 0.896 | 0.836 | 0.834 |
| 3. Expand product assortment | 0.750 | 0.727 | 0.639 | 0.587 |
| 4. Enter new markets or increase market share | 0.864 | 0.688 | 0.776 | 0.807 |
| 5. Increase flexibility of production | 0.227 | 0.455 | 0.432 | 0.350 |
| 6. Reduce labor costs | 0.591 | 0.688 | 0.607 | 0.682 |
| 7. Reduce use of materials | 0.409 | 0.558 | 0.536 | 0.556 |
| 8. Reduce use of energy | 0.227 | 0.286 | 0.464 | 0.556 |
| 9. Fulfill government regulation or standards requirements | 0.205 | 0.260 | 0.257 | 0.345 |
| 10. Mitigate environmental damage | 0.273 | 0.390 | 0.344 | 0.422 |
| **Observations** | 44 | 77 | 183 | 223 |

**Table 5 R&D and training investments and innovation outcomes**

| | Log(ALL INNOVATION SALES) | | | Log(ALL INNOVATION SALES) | | |
|---|---|---|---|---|---|---|
| | Coeff. | SE | p | Coeff. | SE | p |
| Intercept | -14.844 | 2.523 | 0.000 | -14.284 | 2.495 | 0.000 |
| Product innovation (1996) | 4.517 | 1.197 | 0.000 | 4.233 | 1.185 | 0.000 |
| Log(employees) | 1.350 | 0.407 | 0.001 | 1.431 | 0.403 | 0.000 |
| Business group | -0.598 | 1.146 | 0.602 | -0.828 | 1.132 | 0.465 |
| Exports/sales | 0.783 | 1.767 | 0.658 | 0.954 | 1.749 | 0.586 |
| Manufacturing*Log(R&D exp.) | 0.915 | 0.269 | 0.001 | 0.367 | 0.310 | 0.237 |
| Service*Log(R&D exp.) | 1.269 | 0.347 | 0.000 | 0.655 | 0.425 | 0.124 |
| Manufacturing*Log(training exp.) | 0.307 | 0.247 | 0.213 | 0.382 | 0.244 | 0.119 |
| Service*Log(training exp.) | 0.384 | 0.440 | 0.383 | 0.357 | 0.436 | 0.413 |
| Manufacturing*Regular R&D | | | | 4.577 | 1.422 | 0.001 |
| Service*Regular R&D | | | | 5.801 | 2.588 | 0.025 |
| Sigma | 9.475 | 0.432 | 10.325 | 9.324 | 0.425 | 10.159 |
| Log likelihood | -1283.07 | | | -1275.36 | | |
| Pseudo $R^2$ | 0.070 | | | 0.075 | | |

Notes: Tobit ML models include 2-digit industry dummies. 533 observations.

**Table 6 Breadth of knowledge sources and innovation objectives**

*Dependent variable: Log(all innovation sales)*

| | (1) | | | (2) | | | (3) | | | (4) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | SE | p | Coeff. | SE | p | Coeff. | SE | P | Coeff. | SE | P |
| Intercept | -14.697 | 2.426 | 0.000 | -15.500 | 2.654 | 0.000 | -14.783 | 2.571 | 0.000 | -16.012 | 2.870 | 0.000 |
| Product innovation (1996) | 4.085 | 1.176 | 0.001 | 4.020 | 1.177 | 0.001 | 4.054 | 1.181 | 0.001 | 3.921 | 1.177 | 0.001 |
| Log(employees) | 1.172 | 0.399 | 0.003 | 1.180 | 0.401 | 0.003 | 1.293 | 0.396 | 0.001 | 1.204 | 0.401 | 0.003 |
| Business group | -1.224 | 1.131 | 0.280 | -1.312 | 1.134 | 0.248 | -0.748 | 1.130 | 0.508 | -0.823 | 1.137 | 0.469 |
| Exports/sales | 0.900 | 1.726 | 0.602 | 0.967 | 1.733 | 0.577 | 1.034 | 1.735 | 0.551 | 0.955 | 1.730 | 0.581 |
| Institutionalized R&D | 4.439 | 1.248 | 0.000 | 4.447 | 1.246 | 0.000 | 4.633 | 1.249 | 0.000 | 4.664 | 1.243 | 0.000 |
| Log(R&D expenditure) | 0.442 | 0.271 | 0.104 | 0.453 | 0.273 | 0.097 | 0.469 | 0.272 | 0.085 | 0.513 | 0.273 | 0.061 |
| Log(training expenditure) | 0.341 | 0.214 | 0.111 | 0.358 | 0.214 | 0.095 | 0.347 | 0.215 | 0.107 | 0.391 | 0.215 | 0.070 |
| Sum of important knowledge sources | 0.571 | 0.234 | 0.015 | | | | | | | | | |
| Complex* Sum of important knowledge sources | | | | 0.377 | 0.314 | 0.231 | | | | | | |
| Discrete* Sum of important knowledge sources | | | | 0.716 | 0.305 | 0.019 | | | | | | |
| KIBS* Sum of important knowledge sources | | | | 0.904 | 0.513 | 0.079 | | | | | | |
| Network* Sum of important knowledge sources | | | | 0.492 | 0.546 | 0.369 | | | | | | |
| Sum of important objectives | | | | | | | 0.319 | 0.212 | 0.133 | | | |
| Complex* Sum of important objectives | | | | | | | | | | 0.310 | 0.292 | 0.288 |
| Discrete* Sum of important objectives | | | | | | | | | | 0.515 | 0.278 | 0.065 |
| KIBS* Sum of important objectives | | | | | | | | | | 0.744 | 0.452 | 0.100 |
| Network* Sum of important objectives | | | | | | | | | | -0.774 | 0.594 | 0.194 |
| Sigma | 9.274 | 0.423 | | 9.260 | 0.422 | | 9.310 | 0.424 | | 9.258 | 0.422 | |
| Log likelihood | -1273.24 | | | -1272.55 | | | -1275.09 | | | -1272.61 | | |
| Pseudo $R^2$ | 0.077 | | | 0.077 | | | 0.075 | | | 0.077 | | |

Notes: Tobit ML models include 2-digit industry dummies. 533 observations.

**Table 7 Interaction effects between innovation objectives, regular R&D, and sector**

*Dependent variable: Log(all innovation sales)*

| | Coeff. | | p | Coeff. | SE | P | Coeff. | SE | P |
|---|---|---|---|---|---|---|---|---|---|
| Intercept | -13.665 | 2.887 | 0.000 | -14.060 | 2.712 | 0.000 | -15.736 | 2.846 | 0.000 |
| Product innovation (1996) | 3.955 | 1.185 | 0.001 | 4.094 | 1.179 | 0.001 | 3.948 | 1.173 | 0.001 |
| Log(employees) | 1.246 | 0.400 | 0.002 | 1.312 | 0.401 | 0.001 | 1.198 | 0.400 | 0.003 |
| Business group | -0.640 | 1.136 | 0.574 | -0.608 | 1.129 | 0.591 | -0.728 | 1.135 | 0.521 |
| Exports/sales | 1.100 | 1.735 | 0.526 | 1.055 | 1.729 | 0.542 | 1.093 | 1.722 | 0.526 |
| Regular R&D | 2.610 | 2.746 | 0.342 | 3.507 | 1.340 | 0.009 | 3.811 | 1.286 | 0.003 |
| Log(R&D expenditure) | 0.482 | 0.272 | 0.077 | 0.483 | 0.273 | 0.077 | 0.520 | 0.273 | 0.057 |
| Log(training expenditure) | 0.358 | 0.215 | 0.096 | 0.332 | 0.214 | 0.122 | 0.370 | 0.214 | 0.085 |
| Sum of important objectives | 0.113 | 0.327 | 0.729 | | | | | | |
| Sum of important objectives*regular R&D | 0.355 | 0.430 | 0.410 | | | | | | |
| Sum of important objectives*service | | | | -0.482 | 0.491 | 0.327 | | | |
| Sum of important objectives*manufacturing | | | | 0.367 | 0.224 | 0.101 | | | |
| Sum of important objectives*service*regular R&D | | | | 0.901 | 0.413 | 0.030 | | | |
| KIBS* Sum of important objectives | | | | | | | 0.776 | 0.449 | 0.085 |
| Network* Sum of important objectives | | | | | | | -1.611 | 0.718 | 0.025 |
| Complex* Sum of important objectives | | | | | | | 0.343 | 0.291 | 0.238 |
| Discrete* Sum of important objectives | | | | | | | 0.541 | 0.277 | 0.051 |
| Network* Sum of important objectives*regular R&D | | | | | | | 1.145 | 0.498 | 0.022 |
| Sigma | 9.301 | 0.424 | | 9.269 | 0.422 | | 9.216 | 0.420 | |
| Log likelihood | -1274.75 | | | -1272.58 | | | -1269.85 | | |
| Pseudo $R^2$ | 0.076 | | | 0.077 | | | 0.079 | | |

Notes: Tobit ML models include 2-digit industry dummies. 533 observations.