Service innovation in manufacturing firms: Evidence from Spain

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ABSTRACT

The ways in which manufacturing firms come to offer services to customers servitisation or servicisation are attracting considerable attention. This paper examines an innovation survey of Spanish firms in order to investigate one aspect of this phenomenon: the introduction of new or improved services by manufacturers. Specifically, the paper analyses the determinants of service innovations in manufacturers and determines whether they differ from those of product or process innovations in these same firms. The study finds that almost 20 percent of the firms in the sample have introduced such services in the recent past and that important differences exist between service and product (goods) innovations, with service innovations being particularly related to human resource development and closer links to customers. This suggests that service innovation by manufacturers has much in common with the innovation patterns detected in service sector firms. Intriguing differences across manufacturing sectors are also noted, with the lowest and highest tech sectors reporting more service innovations than the medium tech sectors.

1. Introduction

Services play a key role in developed economies. Market services have become the main driver of the economy and the major contributor to productivity growth, especially as the use of information and communication technology (ICT) services has grown. Moreover, services are the main source of job creation across the OECD area (OECD, 2005). In the European Union (EU 27), the contribution of services to the gross value added was approximately 72 percent, while that of industry was 20.1 percent. Focusing specifically on Spain, the contribution of services to the gross value added was around 70 percent, a similar percentage to the average of the EU 27 (Eurostat, 2009).

In many developed countries the distinction between the manufacturing and the service sector has faded, with the distinction between goods production and service activities becoming increasingly blurred (Lay, 2002). Each sector has taken on some characteristics of the other (Miles, 1993). Indeed, in manufacturing industries, increasing competition is driving firms to offer services with their products. Services may be important for manufacturing firms, because service components are often integral to the delivery, consumption and use of tangible goods (Bharadwaj et al., 1993).

Scholars use various terms to refer to this growth in the importance of services, servitisation (Vandermerwe and Rada, 1988; Baines et al., 2009) and servicisation (Quinn et al., 1990) being the most common, though some authors also refer to it as the rise of product service systems (Johnstone et al., 2009; Pawar et al., 2009; Martinez et al., 2010). The idea of service dominant logic, meanwhile, stresses the fact that some firms acquire goods in order to supply services to their customers or to allow them to self service (Vargo and Lusch, 2004). Recognition of this logic may lead firms to rethink their product offerings so as to be able to compete in terms of the services delivered.

Servitisation of manufacturing firms was first discussed by Vandermerwe and Rada (1988), who refer the process of creating value by adding services to product offerings. This process is seen as being driven by ever more complex customer demands and a need to defend against competition. In effect, manufacturing firms become service providers (Lay et al., 2009), a shift that requires them to change their strategies and develop new business concepts (Neu and Brown, 2005). A diverse range of servitisation examples can be found in the literature on car manufacturers, aerospace industry, machine tools, printing machinery and other capital equipment (Baines et al., 2009). Typical examples of the services provided include installation and training, after sales services (including product repair and maintenance, customer support and recycling of goods at the end of their lifetime), inspection and financial or insurance services. Interest in this topic is growing in academia, business and government (Hewitt, 2002), an interest largely based on a belief that a move towards

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service will create additional value adding capabilities for traditional manufacturers. In essence, the literature suggests that manufacturing firms servitise for three reasons: financial, strategic and marketing (Baines et al., 2009).

Although servitisation of manufacturing firms is not a new phenomenon (for earlier discussions without the terminology see Mathe and Shapiro, 1993), these firms are now gaining an ever higher share of their turnover from selling services (Pawar et al., 2009). The relevance of services that are produced and marketed by manufacturers is by no means anecdotal. Table 1 presents evidence on the share of services in the output of various manufacturing sectors and European countries in 2007. Although clear differences exist among several countries (Holland has the highest percentage of servitisation) and sectors (the manufacture of tobacco products in the UK and of communication equipment in Holland are notable), the average level of servitisation is around 6 percent. In the specific case of Spain, the degree of servitisation of its manufacturing firms is near to the average (similar to Italy and Germany), with some sectors such as 'Publishing, printing and reproduction of recorded media' and 'Recycling' showing degrees of servitisation that are significantly above the average.

The process of servitisation is transforming manufacturing firms into more service like entities. This transformation can change firms' modus operandi and their perception of innovation, changes that substantially affect the innovation process. Firms are aware that delivering services is often more complex than manufacturing products, requiring different approaches to be developed. As noted by Gebauer et al. (2008: p. 387), "a typical problem associated with product related service innovation refers to the fact that new service innovation tends to be a haphazard process: it simply happens." This is an unusual study in that it uses interviews to examine the antecedents for innovation of product related services. In fact, few studies have explored the servitisation process, thus leaving us with little information with which to inform practitioners (Baines et al., 2009). Research in the area would benefit from insights attained from quantitative analyses (Gebauer et al., 2008).

Our work advances in this direction by theoretically and empirically examining whether some factors traditionally associated with innovation in service firms may also have a positive impact on the introduction of new services in manufacturing firms. Furthermore, we investigate if these factors exert a differential effect on the achievement of product and process innovations that are typical of the manufacturing sector. In theoretical terms, then, this study casts light on the literature on service innovation by analysing different factors traditionally related to service innovations and discussing their relevance in manufacturing contexts. In following this idea, this study contributes to the most recent approach on innovation in services the synthesis approach by considering the growing interdependence between manufacturing and services and by delving more deeply into traditional factors in service innovations that may be relevant in both contexts (Coombs and Miles, 2000). In empirical terms, an important contribution of this paper consists in providing evidence on the antecedents necessary for the innovation of services by manufacturing firms, a neglected topic in the literature. More specifically, we use a quantitative approach to analyse some determinants of service innovation in manufacturing firms and to explore whether these determinants exert a different impact on traditional innovation outcomes in manufacturing firms (e.g., product and process innovations). Additionally, we attempt to understand the role of the typical innovation drivers in manufacturing firms (e.g., R&D activities) in achieving service innovations. Thus, the paper concentrates on human capital and training, the role of advanced technologies (e.g., IT) and collaborative interaction with customers as the usual drivers of service innovation. Beyond this, the study examines a variety of traditional determinants of innovation in manufacturing firms. Our empirical study uses data from the Spanish Technological Innovation Panel on a large sample of firms in different manufacturing sectors for the period 2004 2007. The results and conclusions reached allow us to outline some practical recommendations for manufacturing firms interested in offering new services associated to their products.

Table 1
Weight of services in the sales of European manufacturing firms[a].
Source: *Eurostat*.

	Spain	*Italy*	*Portugal*	*Germany*	*U.K.*	*Sweden*	*Denmark*	*Belgium*	*Netherlands*	***Average by sector***
Manufacture of food products and beverages	3.54	3.44	2.00	4.01	4.67	5.86	0.50	4.33	4.62	***3.66***
Manufacture of tobacco products	4.90	2.13	0.64	12.56	40.18	n.a.	14.64	11.19	3.91	***11.27***
Manufacture of textiles	2.63	4.97	1.15	4.18	6.33	6.47	0.41	3.77	6.62	***4.06***
Manufacture of wearing apparel; dressing and dyeing of fur	3.51	0.15	1.13	4.63	7.22	13.72	0.58	8.17	8.83	***5.32***
Manufacture of leather and footwear	2.04	3.77	0.68	3.71	5.82	1.19	2.86	11.12	9.12	***4.47***
Manufacture of wood and cork	1.80	5.96	1.78	2.66	4.94	2.28	0.40	5.44	5.68	***3.44***
Manufacture of pulp, paper and paper products	1.89	1.36	0.58	3.24	5.10	3.47	0.86	4.40	4.52	***2.82***
Publishing, printing and reproduction of recorded media	14.55	2.82	1.31	3.41	25.93	5.43	2.82	5.94	5.38	***7.51***
Manufacture of coke, refined petroleum and nuclear fuel	1.03	0.76	1.92	9.42	5.47	0.43	0.05	11.37	3.43	***3.76***
Manufacture of chemical and chemical products	6.46	8.21	1.35	8.91	9.31	18.71	1.94	5.96	7.47	***7.59***
Manufacture of rubber and plastics products	5.39	4.41	1.57	4.85	3.61	3.93	1.24	5.73	5.32	***4.00***
Manufacture of other non-metallic mineral products	3.68	3.57	2.46	6.36	4.13	5.98	1.32	4.50	6.12	***4.24***
Manufacture of basic metals	1.32	1.42	0.73	1.53	2.17	2.31	0.26	0.91	3.82	***1.61***
Manufacture of fabricated metal products	2.58	1.91	1.52	3.39	2.77	2.08	0.35	0.91	17.12	***3.63***
Manufacture of machinery and equipment	6.17	3.50	1.54	3.32	5.29	9.80	3.19	8.90	10.76	***5.83***
Manufacture of office machinery and computers	6.78	12.10	0.13	18.71	4.76	8.13	17.51	16.63	12.71	***10.82***
Manufacture of electrical machinery and apparatus	4.52	5.57	1.80	4.42	5.27	22.11	0.39	6.49	22.61	***8.13***
Manufacture of radio, TV and communication equipment	9.19	8.26	0.61	7.71	8.62	n.a.	2.45	12.31	59.68	***13.60***
Manufacture of medical, precision & communication equip.	7.41	4.54	0.84	5.47	7.71	8.45	2.10	6.22	21.73	***7.16***
Manufacture of motor vehicles, trailers and semi-trailers	2.45	10.28	1.61	4.88	8.29	16.68	0.30	3.03	5.32	***5.87***
Manufacture of other transport equipment (ships, aircrafts…)	4.32	13.86	0.37	4.39	8.54	11.97	0.42	1.31	9.18	***6.04***
Other manufacture (furniture, games and toys, jewellery…)	5.41	3.08	1.29	3.71	5.63	4.98	4.72	10.15	37.47	***8.49***
Recycling	13.89	13.82	4.97	5.12	4.67	3.67	0.09	1.18	20.85	***7.95***
Average by country	***5.02***	***5.21***	***1.39***	***5.68***	***8.26***	***7.51***	***2.58***	***6.52***	***12.71***	**6.09**

[a] Figures are percentages out of total production of each sector (year 2007).

The remainder of the paper is organised as follows. In the next section, we present the conceptual foundations that underlie servitisation and service innovations, as well as some theoretical arguments and research expectations concerning the determinants of service innovation in manufacturing firms. We then go on to describe the database and methodological approach, followed by the empirical results. Lastly, we discuss the findings, implications and limitations of our research.

2. Literature review and research model

2.1. Process of servitisation

Services can complement the sale and help increase the demand for a tangible product, thus making them potentially crucial for the growth and competitiveness of manufacturing firms (Mathe and Shapiro, 1993). These firms offer new services to improve the acceptability, functionality, flexibility and performance of existing goods (Howells, 2004). Adding services to a product offering, then, is a way to differentiate products (Gebauer and Friedli, 2005) and enhance customer loyalty (Baines et al., 2009). Some scholars argue that the resulting product service combinations tend to be less sensitive to price based competition (Malleret, 2006). Product related services, however, can also work to sustain growth in more mature industries (Wise and Baumgartner, 1999), where market expansion and technological innovation are relatively slow (Oliva and Kallenberg, 2003). Furthermore, not all services sold by manufacturing firms support the use of their goods; R&D and testing services, data network services and other capabilities initially developed to support production processes may also be offered. Of course, the development of profitable services in manufacturing firms is far from systematic and immediate (Malleret, 2006). The complexity of service strategies within manufacturing sectors may make their implementation difficult (Mathieu, 2001). Some manufacturing firms find it hard to make the transition to services, an example being the difficulties encountered by a computer firm seeking to offer IT awareness training services. Apart from attempting to enter unfamiliar markets with a new offering, this firm has sales and marketing staff geared up to selling kit rather than services, and it lacks the staff to support large scale ongoing use of the new service. Notwithstanding the augmentation of services provided along with the corresponding increases in revenue firms are still unable to translate the returns from the new activity into profits. In line with this, Neely (2008) identifies a paradox of servitisation with his finding that servitised firms in the US generate higher revenues but deliver lower profits than pure manufacturing firms.

Although the financial benefits of servitisation do not seem automatic, many firms see it as a way of increasing switching costs that can make market penetration by rivals and potential new competitors extremely difficult (Mathe and Shapiro, 1993). Indeed, the literature suggests strategic factors (e.g., to maintain competitive advantage) as another reason to pursue a servitisation strategy (Baines et al., 2009). Marketing opportunities are also identified as an argument for using services to sell more products (Mathe and Shapiro, 1993; Gebauer and Fleisch, 2007). After considering these different business reasons (financial, strategic and marketing) and weighing the potential benefits and opportunities against the risks and costs of servitisation, manufacturing firms may decide to opt for a combination of product and service offerings. This process can occur in different ways:

- The first approach is to offer the manufactured products along with closely related services in a single package, aiming to make them more attractive than those of their competitors. For example, vehicle manufacturers may offer services linked to financing, insurance, maintenance, leasing or disposal to facilitate the purchase of their cars and trucks. Another typical example is found in reprographic equipment manufacturers. Firms like Rank Xerox offer repair, maintenance and leasing services along with the photocopier.
- A second and more sophisticated approach is to offer the consumer not the product itself, but rather the goal that the purchase of the manufactured product will ultimately fulfil, the functionality it will provide. Firms in the computer industry, for instance, may offer to perform computing services rather than supply the actual computers (Howells, 2004). Cloud computing is an example that is attracting a great deal of current interest. A less high tech example is illustrated by Tetra Pak, originally a supplier of aluminium lined juice cartons. This firm licences to others the right to produce juice cartons; the firm also produces and sells the equipment to package the beverage, along with the computerised numerically controlled system and software to run the packaging operations. Its expertise enables it to offer consulting services as well (Mathe and Shapiro, 1993).
- A third approach involves improving the acceptability of a product by overcoming obstacles to its adoption or use. An example is Greif Packaging, a supplier of metal drums for shipping bulk chemicals. The firm realized that customers did not want to buy their own steel drums, but did need to move toxic chemicals efficiently and safely. To meet these needs, Greif converted its business model to become a trip leasing company for specialty chemicals, drum supply, cleaning, refurbishing, regulatory compliance, transportation and tracking (Warren and Susman, 2004).

2.2. Characteristics of services and their innovation process

Although services are highly heterogeneous and no consensus on their basic features exists, they typically differ in important ways from products. Miles (1993) classifies some of these specificities via four dimensions: service production, service nature, service consumption and service markets (see Table 2). Of these specificities, we would highlight the relevance of human capital for services production and management, the critical role of customers and consumers and the importance of information.

The distinctive characteristics of services are likely to have direct implications for the conceptualisation and definition of innovation (Sirilli and Evangelista, 1998). These characteristics have led many researchers to suspect that innovation by service firms will differ in its fundamental features and elements from innovation by manufacturing firms (Preissl, 2000; Drejer, 2004; Tether, 2004; Freel, 2006; among others). Some of the main differences that are mentioned relate to the following: the increased importance of the human capabilities, as human capital is relatively more important in services (Pires et al., 2008); the greater importance of 'organisational' factors and technologies that favour high levels of connectivity and interaction among different components and the transfer of information associated with service innovations (Rubalcaba et al., 2010); the greater difficulty in protecting service innovations, due to the complexity of defining appropriation regimes of innovation results; the need to engage customers in design and/or implementation of innovations, as the relationship with customers is a fundamental aspect of service innovations (Coombs and Miles, 2000; Hipp and Grupp, 2005). In summary, numerous factors exist that may be important determinants of service innovations. These factors largely lie in human capital, information technology and the relationship with

Table 2
Services characteristics.

Service production	• Specialist knowledge and human capital are key competitive factors in services production • Some services highly professional (especially requiring interpersonal skills), other relatively unskilled (often involving casual part-time labour) • Workforce often engaged in craft-like production with limited management • Economies of scale are limited • Low levels of capital equipment; heavy investment in buildings
Service nature	• Services are non-material, intangibles • Often information-intensive • Hard to store or transport • Process and product hard to distinguish • Often customised to consumer requirement
Service consumption	• Close interaction between production and consumption, in time and space • Services are 'consumer-intensive', requiring inputs from consumer into design/production process • Delivery of products is also a fundamental aspect • Often hard to separate production from consumption
Service market	• Some costs are invisibly bundled with goods • Professional regulation common in some services • Difficult to demonstrate product in advance

Adapted from Miles (1993).

customers. This evidence, however, focuses on service sector firms. The question that remains to be answered is whether these 'service related' factors also apply to the innovation process of manufacturing firms looking to develop new services.

2.3. *Service innovation in manufacturing firms*

Given their importance for service innovations, this paper focuses on the following dimensions as 'service related' factors: human capital and training; the role of advanced technologies; co operation with customers. The study then goes on to propose a research model of service innovation in manufacturing firms that takes into account these 'service related' factors and other tradi tional 'manufacturing related' factors that typically explain pro duct and/or process innovations such as R&D activities, other technological partnerships (e.g., suppliers, competitors or research organisations) and activities of market prospection.

2.3.1. *Human capital and training activities*

Johnson et al. (1996: p. 113) note that "in the service sector, knowledge itself is the product and human capital is the domi nant form of capital." Accordingly, human capital is an essential resource for innovation in general and even more so for service innovations (Pires et al., 2008). Investment in human resources, then, plays an especially important role in service innovations (Miles, 2001). Research indicates that a lack of qualified personnel may constitute a barrier to this kind of innovation (Sirilli and Evangelista, 1998), with one survey of European service firms concluding that the lack of highly educated personnel is an obstacle, particularly for knowledge intensive services (Sundbo and Gallouj, 1998). The important role played by the human factor in production and delivery of services should be associated with substantial investment in human resources in service innovators.

Training is a key activity in updating staff knowledge, thereby increasing the human capital of the firm and its absorptive capacity (Cohen and Levinthal, 1990). It creates the human skills that, taken together, are the repository in which the tacit knowl edge of an organisation resides (Johnson et al., 1996). A commit ment to the development of human capital through training programmes is likely to be critical to successful innovation (Freel, 2006).

Statistical evidence also points to the importance of human capital for innovation in a wide range of manufacturing industries and countries (Mohnen and Röller, 2001). Walsworth and Verma (2007) show that training appears to have a positive impact on both product and process innovations. Beugelsdijk (2008) indi cates the importance of training for generating incremental innovations. Amara et al. (2008) find that variables related to learning by training have a relevant impact on the degree of novelty of innovations. Lastly, Rammer et al. (2009) show the importance of applying HRM tools (training among them) to facilitate innovation processes.

The literature suggests that human capital and training are crucial factors for innovation both in manufacturing and service firms. Raja et al. (2010) underline the importance of training requirements, as the development of new skills is a key to supporting the process of servitisation. We expect, then, to find a positive relation between training and service innovations in manufacturing firms. We also explore whether training exerts a different impact on traditional innovation outcomes in manufacturing firms.

2.3.2. *Acquisition of advanced technology*

The intangible nature and information based content of ser vices give information technologies a central role in innovation activities (Miles, 1993). These technologies are relevant for the initiation of new services because they can be tools for better and more systematic information gathering and sharing on competi tors, competing services and new customer needs (de Jong and Vermeulen, 2003). Service firms benefit from technology adoption as a means of creating new services and processes or of improving existing ones (Hipp and Grupp, 2005; Pires et al., 2008).

Advanced technologies allow manufacturing firms to make better use of labour, equipment and materials that result in financial savings and improvements in product quality and reliability. In addition, and more importantly for strategy, these technologies provide gains in flexibility that allow firms to cope better with environmental change and uncertainty (Naik and Chakravarty, 1992; Hofmann and Orr, 2005). Furthermore, technology adoption can trigger an interactive learning process that helps a firm to develop its learning and distinctive competences (Pandza et al., 2005; Sohal et al., 2006). Many innovations may be achieved during the process of adapting technology that was purchased in the market, a process that primarily aims to make the technology function adequately in a new environment (Hansen and Serin, 1997). In line with this, recent work by Raymond et al. (2009) shows how the use of advanced manufacturing technologies posi tively influences product innovations in SMEs.

These arguments suggest that advanced technologies enhance innovativeness both in manufacturing and service contexts. Thus, we expect to find that using advanced technologies has a positive impact on service innovations in manufacturing firms. Once again, we will explore its differential effect on manufacturing innovation outcomes.

2.3.3. *Interaction with customers*

Interaction with customers is a distinctive and in some services a fundamental element of the service process. Service

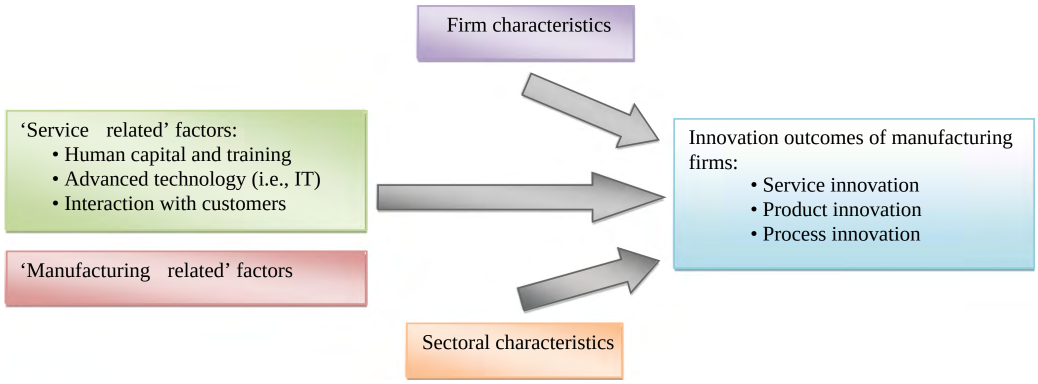

Fig. 1. Determinants of service innovation in manufacturing firms.

providers, then, must develop not only the service itself, but also the precise manner in which it is delivered to customers (Johne and Storey, 1998). As a result of the interaction between service providers and their customers, some innovation activities are aimed at adapting the services to the users' needs, which might in itself be considered a form of innovation. Previous European surveys find that the more innovative the firm, the more important are the customers as a source of information (Sundbo and Gallouj, 1998). Related to this point, the OECD (2001) indicates that research in service organisations is often aimed at improving the interface with customers.

When innovation is expensive, sharing the costs is a logical response. Given the level and specificity of the costs attached to the implementation of a service strategy, collaboration could be an attractive option for manufacturing firms (Mathieu, 2001). Collaborative interaction with customers would be particularly beneficial, because strongly customer centred approaches form a key feature of servitisation (Baines et al., 2009). Customers are not just provided with products but with more broadly tailored solutions, typically purchasing a mixture of services and goods (Vandermerwe, 1993; East, 1997). Thus, interaction with customers could be an interesting source of ideas for service innovations. We expect, then, to find that collaborating with customers has a positive influence on service innovation in manufacturing firms. As in the two previous 'service related' factors, we analyse the different impact of customers on service, product and process innovations.

2.3.4. Research model and research questions

The arguments in the previous sections allow us to formulate the following research questions:

RQ1: Do some 'service related' factors determine service innovation in manufacturing firms?

RQ2: Do these 'service related' factors have a different impact on product and/or process innovations in these manufacturing firms?

Service innovation in manufacturing firms cannot be viewed in isolation from the factors that typically lead these firms to achieve product and/or process innovations. We propose, then, that any analysis of the factors that lead to service innovation in manufacturing firms must also take into account the factors that have been traditionally linked to the achievement of product and process innovations in a manufacturing context. Thus, we need to explore whether the factors that typically lead manufacturing firms to achieve product and/or process innovations (i.e., 'manufacturing related' factors) will also exert an impact on the generation of service innovations.

Fig. 1 summarises the determinants of service innovation in manufacturing firms included in our research model.

3. Methodology

3.1. Sample and data

The empirical analysis is based on the Spanish Technological Innovation Panel (TIP). This panel is compiled by Spain's National Statistics Institute (INE), Science and Technology Foundation (FECYT) and Foundation for Technical Innovation (COTEC). The data come from the Spanish Community Innovation Survey (CIS). The panel provides information on different aspects of innovation in firms, along with more general data and economic information for a wide and representative sample of firms. Like many other European innovation surveys (such as CIS), the panel is biased towards firms with strong innovation capabilities, a point that must be taken into account when interpreting the empirical results. The TIP collects data on firms for different years from all sectors of the Statistical Classification of Economic Activities in the European Community (NACE).

Despite the relatively recent availability of this data source, it has already been used by many other researchers (Molero and García, 2008; Un and Montoro Sánchez, 2010; Vega Jurado, et al., 2009; among others). Moreover, given that the TIP is a CIS type database, it has been used both by policy observers to provide innovation indicators and trend analyses, and by economists to analyse a variety of innovation related topics. This study, then, is constructed on widely accepted innovation indicators and variables (for a review of CIS based studies, see van Beers et al., 2008; Mairesse and Mohnen, 2010).

Our empirical analysis is based on the unbalanced panel of 23,972 manufacturing firms for the period 2004 2007. The final sample used in the models, however, contains 12,334 observations due to the introduction of two lagged period variables.

3.2. Variables

3.2.1. Dependent variables

The dependent variables relate to firm innovation performance for the years 2006 and 2007. For each year, firms declare if they have achieved any innovation result in the last two years. Thus, the innovation outputs that are declared in the 2007 survey should have been achieved in 2006 and/or 2007.

In order to capture the different innovation outputs, we use three separate measures: service innovation; product innovation; process innovation. Service innovation (*SERVICE*) is assumed to happen when the firm indicates (i) new services have been introduced into the market, or (ii) existing services have been significantly improved or important changes have been made to their basic characteristics, intangible components or desired purposes. This is a dichotomous variable that takes value 1 when the firm introduces new services; otherwise its value is 0.

Product innovation (*PRODUCT*) is assumed to happen when the firm declares it has introduced products (goods) into the market that are new or that offer a significant improvement on the basic characteristics, technical specifications, incorporated software or any other components or materials. Product innovation is a dichotomous variable that takes value 1 when product innovation has occurred; otherwise its value is 0.

Process innovation (*PROCESS*) is assumed to happen when the firm indicates it has implemented new or significantly improved production processes, distribution methods or support activities for its goods and services. It is also a dichotomous variable.

3.2.2. *Independent variables*

The independent variables are selected on the basis of their relevance to firms' innovation activities. In order to avoid problems of simultaneity with the innovation results, all the independent variables are lagged two periods. These variables are lagged two periods, instead of the usual one period, because the dependent variables are referred to a two year period in the questionnaire and we need to avoid simultaneity between dependent and independent variables. Several robustness checks were also performed with independent variables lagged one year, with almost identical results to those presented in the models.

A range of innovation activities is introduced in the empirical model, including the variables needed to analyse our expectations (all as dichotomous variables). In line with our research model (see Fig. 1), we split our independent variables into two groups: 'service related' and 'manufacturing related' factors.

For 'service related' factors, we distinguish three dichotomous variables: TRAINING, TECHNOLOGY and CUSTOMERS. *TRAINING* captures whether the firm has trained its employees through internal or external training activities specifically oriented to develop new products, services or processes, or to significantly improve the current ones. The variable takes value 1 if the firm declares that it has trained its employees through internal or external training activities. *TECHNOLOGY* captures whether the firm has acquired machinery, equipment and advanced technology or hardware and software aimed at improving innovation processes. The variable takes value 1 if the firm declares that it has acquired this kind of technology. *CUSTOMERS* capture whether the firm has engaged in technological collaboration with customers. The variable takes value 1 if the firm declares that it has collaborated with customers.

For 'manufacturing related' factors, we include variables that are typically used to analyse the innovation process of manufacturing firms. Specifically, we analyse R&D activities (both internal and external), collaboration with other partners beyond customers (suppliers, research organisations and competitors) and market prospecting activities.

R&D activities are seen as the conventional way of achieving innovations in manufacturing settings (Santoro and Chakrabarti, 2002). Moreover, previous empirical research suggests that in house and external R&D are complementary (Cassiman and Veugelers, 2006). For this reason we feel it is important to include the performance of internal R&D and the acquisition of external R&D separately via two dichotomous variables. Internal R&D (*INT R&D*) captures the decision to perform formal expenditures on R&D activities in house. The variable takes value 1 if the firm declares that it has incurred internal R&D expenses. External R&D (*EXT R&D*) captures the decision to acquire external R&D services via a contract, agreement, etc., as well as the acquisition of these services from other firms, public administrations, universities, or organisations. The variable takes value 1 if the firm declares that it has incurred external R&D expenses.

Along with the decision to perform internal and external R&D, then, we have taken into account that the innovation process of manufacturing firms may benefit from other sources of knowledge flows such as technological collaboration (Belderbos et al., 2004; Faems et al., 2005; Nieto and Santamaria, 2007, among many others). Collaboration with suppliers allows firms to enhance flexibility, product quality and market adaptability (Chung and Kim, 2003). Collaboration with research organisations is likely to increase a firm's research capabilities and allow it to conduct research at the technological frontier (Miotti and Sachwald, 2003). Collaboration with competitors makes it possible to perform basic research and establish standards (Tether, 2002). Our study analyses these types of collaborations via three dichotomous variables: *SUPPLIERS* capture whether the firm has engaged in technological collaboration with suppliers; *RESEARCH ORG* captures whether the firm has engaged in technological collaboration with research organisations (universities, technology institutes, etc.); *COMPETITORS* capture whether the firm has engaged in technological collaboration with competitors.

Lastly, market prospecting is regarded as a tool for anticipating future development, technological trends and related market opportunities (Stanovnik and Kos, 2007). It has become a vital activity for manufacturing firms to meet the challenges of a rapidly changing environment and is an effective tool for establishing technological strategies (Barge Gil et al., 2011). In fact, market prospecting plays an important role in making strategic decisions such as the offering of services by manufacturing firms. The dichotomous variable *MARKET* captures the firm's decision to perform activities such as market prospecting and other efforts to prepare for the introduction of innovations in the market.

3.2.3. *Control variables*

According to the research model described in Fig. 1, to understand the innovation process of manufacturing firms we should control for firm and sector characteristics. Regarding firm characteristics, the logarithm of the total innovation expenses (*INN EFFORT*) is included to control for the effort made by the firm to achieve innovation. This variable captures the capacity of the firm to absorb, exploit and transform knowledge into new products, services and processes. Firm size (*SIZE*) is another common explanatory variable of innovation behaviour (Colombo and Garrone, 1996). The logarithm of sales is used as a proxy for the size of the firm.

Numerous studies recognise the effect of ownership structure on innovation and track its influence by focusing on foreign ownership, notwithstanding the fact that the empirical evidence is not conclusive (see Becheikh et al. 2006). In line with this practise, we include a dichotomous variable to indicate whether the firm belongs to a group of companies (*GROUP*). To control for its potential impact, a dichotomous variable that captures whether more than 50 percent of the firm's capital is foreign owned is included (*FOREIGN OWN*). The European Union (EU) market is introduced (as a dummy variable) to control for the presence of the firm in these international markets (*EU MK*). In addition, we include another dummy variable to control for whether the firm is selling its products in foreign markets outside the EU (*OVERSEAS MK*). Lastly, four dummy variables capture potential differences between the determinants of innovation outputs depending on manufacturing sector characteristics. We use the OECD's (2005) classification of manufacturing industries based on technology and R&D to form four groups: low tech (*LT*), medium low tech (*MLT*), medium high tech (*MHT*) and high tech (*HT*) firms. *LT* is selected as the reference category and is thus excluded from the models.

Table 3 contains the descriptive statistics and correlations of the independent and control variables used in this study. A description of the definition and measures of the variables included in the empirical analysis is provided in the appendix.

3.3. *Descriptive analysis*

Table 4 displays some descriptive figures on the number and percentage of different innovation outcomes; it provides an overview of the innovation behaviour of the firms in our sample.

A preliminary consideration of these results indicates that as expected product innovations are the most frequent innovation outcome achieved by manufacturing firms (56.51 percent of firms), followed by process innovations (39.43 percent) and lastly service innovations (18.24 percent). The fact that almost one in five manufacturing firms reports introducing service innovations shows that this is by no means an unimportant form of innovation. Given that a mere 104 manufacturing firms in this sample (0.84 percent) achieved service innovations only, it appears clear that these firms are also developing other types of innovations.

We can go beyond this basic descriptive analysis to explore the impact of different innovation activities and sources on service innovations in manufacturing firms. In doing so, we will also try to examine if and explain how these activities and sources differ from those associated with more conventional (technological) product and process innovations.

3.4. *Model specification*

In order to model the simultaneous generation of service, product and process innovations, we use a multivariate probit model. The multivariate modelling approach offers four important improvements over other probit based techniques. First, the usual multinomial model assumes that the innovation decisions are strict substitutes, whereas the multivariate approach allows the modelling of complementary decisions as shown in Table 4, a large number of firms (over 50 percent of the innovators) are simultaneously achieving different innovation outcomes. Second, unlike univariate probit models, the multivariate probit model allows us to incorporate a certain correlation structure for the unobservable factors related to different innovation outcomes. In particular, the model considers the correlations among errors instead of assuming them to be zero or constant. If this is not taken into account (e.g., with three separate probit equations), inefficient estimators result (Belderbos et al., 2004). Third, a related advantage of this cross equation structure of errors is that the specification of the equations (i.e., the independent variables) can vary across dependent variables. Lastly, and most importantly for this study, we can perform comparisons among the variables that are shared across models (again, unlike other probit models). This is critical, since our model is designed to identify (i) activities and sources that explain service innovations in the manufacturing sector, and (ii) whether these activities differ from those necessary to achieve product and process innovations.

Our models were also analysed for potential multicollinearity problems. To test for multicollinearity, an analysis of the variance inflation factor (VIF) was conducted. Individual VIF values greater than ten indicate a multicollinearity problem (Neter et al., 1989), along with average VIF values greater than six. The values presented in Table 3 do not reach these levels, indicating that problems of multicollinearity do not exist in any of the models.

Table 3
Descriptive statistics, correlations and collinearity diagnostics of the independent and control variables.

		Mean	St. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	VIF
1	*INT R&D*	0.715	0.451																		1.43
2	*EXT R&D*	0.359	0.479	0.24																	1.25
3	*TECHNOLOGY*	0.371	0.483	0.18	0.22																1.23
4	*TRAINING*	0.263	0.440	0.25	0.22	0.34															1.33
5	*MARKET*	0.317	0.465	0.28	0.19	0.31	0.40														1.31
6	*CUSTOMERS*	0.087	0.282	0.16	0.18	0.11	0.16	0.13													1.41
7	*SUPPLIERS*	0.131	0.338	0.14	0.20	0.16	0.17	0.14	0.46												1.39
8	*COMPETITORS*	0.052	0.223	0.09	0.15	0.09	0.12	0.10	0.29	0.25											1.15
9	*RESEARCH ORG*	0.187	0.390	0.22	0.34	0.13	0.17	0.16	0.37	0.37	0.28										1.39
10	*INN EFFORT*	9.201	5.452	0.48	0.29	0.23	0.24	0.27	0.18	0.17	0.13	0.24									1.62
11	*SIZE*	15.977	1.829	0.04	0.14	0.12	0.11	0.08	0.08	0.15	0.08	0.12	0.31								1.76
12	*GROUP*	0.360	0.480	0.03	0.11	0.07	0.08	0.04	0.10	0.11	0.06	0.10	0.19	0.55							1.60
13	*FOREIGN OWN*	0.125	0.330	−0.01	0.04	0.03	0.05	0.02	0.06	0.05	0.03	0.01	0.11	0.36	0.43						1.28
14	*EU MK*	0.742	0.437	0.18	0.12	0.11	0.10	0.13	0.07	0.08	0.05	0.10	0.27	0.31	0.15	0.15					1.66
15	*OVERSEAS MK*	0.614	0.487	0.17	0.13	0.09	0.11	0.15	0.09	0.09	0.06	0.11	0.30	0.33	0.18	0.15	0.61				1.71
16	*MLT*	0.253	0.435	−0.07	0.00	−0.00	−0.03	−0.06	−0.02	−0.01	−0.00	−0.01	−0.08	0.04	−0.00	−0.00	−0.04	−0.06			1.37
17	*MHT*	0.328	0.469	0.13	0.02	0.01	0.06	0.09	0.07	0.02	0.02	0.03	0.13	0.01	0.04	0.08	0.09	0.13	−0.41		1.48
18	*HT*	0.106	0.308	0.11	0.07	0.01	0.08	0.05	0.05	0.00	0.05	0.07	0.14	−0.06	0.01	0.04	−0.00	0.03	−0.20	−0.24	1.30
																		Mean VIF			**1.43**

Table 4
Innovation outcomes.

	Selected sample *N* 12,334	
	Number[a]	Percentage[b] (%)
Service innovation	2,250	18.24
Product innovation	6,970	56.51
Process innovation	4,863	39.43
Service & Process & Product	*1,530*	*12.40*
Service & Process only	*329*	*2.67*
Service & Product only	*287*	*2.33*
Process & Product only	*3,475*	*28.17*
Only Service	*104*	*0.84*
Only Process	*2137*	*17.33*
Only Product	*1678*	*13.60*
Non-innovating firms	*2794*	*22.65*

[a] Number of firms that achieve each type of innovation (or combination indicated).
[b] Percentage of firms that achieve each type of innovation (or combination indicated).

Table 5
Multivariate probit analysis: innovation activities.

	Service	Product	Process
Independent variables			
TRAINING	0.173***	0.004	0.149***
TECHNOLOGY	0.101***	0.081***	0.586***
CUSTOMERS	0.175***	0.018	0.034
INT R&D	0.304***	0.501***	0.237***
EXT R&D	0.116***	0.064**	0.037
SUPPLIERS	0.079*	0.065	0.248***
COMPETITORS	0.103*	0.025	0.046
RESEARCH ORG	0.034	0.101**	0.007
MARKET	0.211***	0.631***	0.044
Firm controls			
INN EFFORT	0.045***	0.072***	0.071***
SIZE	0.021**	0.001	0.048***
GROUP	−0.055	−0.024	−0.045
FOREIGN OWN	−0.111**	−0.013	0.020
EU MK	−0.078*	0.109***	0.168***
OVERSEAS MK	−0.001	0.141***	−0.033
Sectoral controls			
MLT	−0.131***	0.028	−0.026
MHT	−0.066*	0.248***	−0.267***
HT	0.014	0.181***	−0.440***
Intercept	−2.062***	−1.381***	−1.609***
ρ_{21}Z	0.261***		
ρ_{31}Z	0.271***		
ρ_{32}Z	0.160***		
$LR; \chi^2 : \rho_{21} \quad \rho_{31} \quad \rho_{32} \quad 0$	421.249***		
Log pseudo-likelihood	−16 356.195		
Wald test of the full model	5 172. 46***		
Number of observations	12 334		

Non-standardised regression coefficients are shown.

* $p \le 0.10$.
** $p \le 0.05$.
*** $p \le 0.01$.

4. Empirical results

Table 5 summarises the multivariate probit results of the impact of different innovation activities on the three innovation outcomes. Of particular interest is that the correlation coefficients of the error terms in the multivariate probit (ρ_{21}, ρ_{31} and ρ_{32}) are positive and highly significant ($p < 0.01$), thus supporting the idea of interdependence of innovation outcomes: firms are motivated

Table 6
Wald tests: results of beta difference tests[a].

	Test: β_i^1	β_j^2	β_i^1 value	β_j^2 value	Chi-sq.	*p*-value
Independent variable:						
TRAINING	$\beta^1_{SERVICE}$	$\beta^2_{PRODUCT}$	0.173***	0.004	**14.14**	**0.000**
	$\beta^1_{SERVICE}$	$\beta^3_{PROCESS}$	0.173***	0.149***	0.25	0.619
	$\beta^2_{PRODUCT}$	$\beta^3_{PROCESS}$	0.004	0.149***	**10.37**	**0.001**
TECHNOLOGY	$\beta^1_{SERVICE}$	$\beta^2_{PRODUCT}$	0.101***	0.081***	0.24	0.621
	$\beta^1_{SERVICE}$	$\beta^3_{PROCESS}$	0.101***	0.586***	**134.45**	**0.000**
	$\beta^2_{PRODUCT}$	$\beta^3_{PROCESS}$	0.081***	0.586***	**147.21**	**0.000**
CUSTOMERS	$\beta^1_{SERVICE}$	$\beta^2_{PRODUCT}$	0.175***	0.018	**4.43**	**0.035**
	$\beta^1_{SERVICE}$	$\beta^3_{PROCESS}$	0.175***	0.034	**3.61**	**0.049**
	$\beta^2_{PRODUCT}$	$\beta^3_{PROCESS}$	0.018	0.034	0.04	0.839

*$p \le 0.10$; **$p \le 0.05$; ***$p \le 0.01$ (two-tailed test).

[a] The coefficients of each independent variable (TRAINING, MACHIN and CUSTOMERS) for each innovation outcome in table 5 (SERVICE, PRODUCT and PROCESS) are shown.

to achieve product and process innovations while pursuing the improvement of services. This result provides strong backing for the choice of multivariate methods. The analysis of the impact of the variables TRAINING, TECHNOLOGY and CUSTOMERS on service innovation provides empirical evidence on our first research question.

Several Wald tests were also performed to analyse the impact of TRAINING, TECHNOLOGY and CUSTOMERS on each innovation outcome in manufacturing firms. The results of these tests (see Table 6) reinforce the empirical evidence provided by the multivariate probit and allow us to answer our second research question on the potentially different impact of these factors on the achievement of service, product and process innovations.

Specifically for the 'service related' factors, engagement in training activities (TRAINING) significantly improves the firm's capability of achieving new services (and processes), but has no effect on product innovations (see Table 5). This shows that skilled employees are essential resources for service innovations. Moreover, as shown in Table 6, the impact of training is statistically higher in service than in product innovations. No statistical difference, however, exists between service and process innovations. The reasons for the importance of training (human resource development) may differ across service and process innovations, as each has its own requirements for such inputs.

Our results indicate that the acquisition of technological equipment and machinery has a positive and significant impact on the probability of developing all three types of innovations: service, product and process. The effect is especially relevant for process innovations (see Table 6), a finding that highlights the importance of information technology as a factor that improves organisational capabilities by connecting different elements inside the firm and ultimately developing processes more efficiently.

As expected with our third 'service related' factor, we find that collaboration with customers (CUSTOMERS) leads to a higher probability of achieving service innovations. Customers have traditionally been seen as a critical source of knowledge and innovation in service industries. What this result suggests, however, is that customers are also highly relevant in manufacturing firms that seek service innovations. A noteworthy result for our second research question is that the impact of partnerships with customers is statistically higher for service innovations than for either product or process innovations (see Table 6).

With respect to the rest of the innovation activities ('manufacturing related' factors), formal R&D exerts a positive and significant impact on the three types of innovation outcomes. In particular, Internal R&D has the greatest impact on the achievement of product innovations. Once again as expected, this type of R&D activity has typically been at the heart of technological innovation in manufacturing firms, especially for product innovations. The coefficients associated with External R&D differ slightly among the three innovation results. The highest effect, however, is found for service innovations. The traditional experience of manufacturing firms may provide a plausible explanation for this finding: since these firms have been more focused on developing new products and/or processes, they require external sources to help them develop or implement new services.

Market prospecting activities (MARKET) are associated with the introduction of service and product innovations, but not with process innovations. This result suggests that a firm concerned with knowing and forecasting market trends and requirements is more likely to improve both products and services, or offer new ones.

Concerning the impact of other partnerships, collaboration with suppliers (SUPPLIERS) exerts a positive and significant impact on process innovations, as expected; it also, however, has a slightly positive effect on service innovations. This may reflect the close connection between service processes and service products, as often seen when, for example, a new IT based service complements new internal practices based on IT use.

Curiously, collaboration with competitors (COMPETITORS) also has a positive and slightly significant effect on the probability of service innovations. That innovators do (sometimes) collaborate with their competitors is no great surprise   indeed, the neologism 'co opetition' was coined precisely to highlight this. In general, collaboration with competitors has been often associated with the need to perform basic research, establish standards, and/or prepare markets. Thus, firms are likely to work with competitors whenever they share common problems that are outside the competitor's area of influence for instance, where innovation requires a regulatory change. In the case of manufacturing firms pursuing service innovations, collaboration with competitors may play an important role in solving common problems (e.g., jointly discovering new markets, etc.). These firms do not typically look for support in this way for their traditional product and process innovations.

Collaboration with research organisations (RESEARCH ORG) only exerts a positive and significant impact on the achievement of product innovations. This result is consistent with the idea that these institutions have traditionally been more focused on providing firms with scientific and technological knowledge (related to product innovation) than on supplying them with intelligence on market needs or the knowledge underpinning service innovations. Several researchers suggest that service sectors may be poorly linked to knowledge adoption activities (Sirilli and Evangelista, 1998; Pires et al., 2008); this argument appears to be generalisable to service innovators within manufacturing firms.

Our results for the control variables confirm previous findings on the effect of firm size on innovation performance. Thus, product innovations are less sensitive to size than process innovations (we infer that larger firms are better at exploiting economies of scale and scope through process innovations). Interestingly, we find that service innovation in manufacturers is also positively influenced by firm size. This evidence is in line with Neely (2008), who finds that larger firms, measured both in terms of numbers of employees and revenues, tend to servitise more than smaller firms.

Regarding the geographical scope of sales, our results suggest that internationalised firms are more likely to achieve product and process innovations, but not service innovations. The implication is that while presence in international markets exerts pressure to improve products and processes, this does not apply to service innovations. The reason for this is unclear. One possibility is that the services offered by competitors overseas are less visible, and thus stimulate innovation less. Another possibility is that service innovations are not a major part of the international offering of the firms concerned; they export their goods, but are less inclined to do so with their new services. This, however, is nothing more than speculation; the issue deserves to be explored further, perhaps through case study research.

Of the other control variables, the results show that belonging to a group has no significant effect on the probability of achieving service innovations. Foreign ownership, meanwhile, shows a slightly negative effect on the likelihood of obtaining service innovations.

Lastly, sectoral characteristics have markedly different impacts on each of the three outputs. The results for service innovations merit particular attention. The negative and significant coefficients of both medium tech categories (MLT and MHT) indicate that firms in the lowest and highest technology intensive sectors are the most likely to introduce service innovations. This is an interesting result that can be explained in various ways. One possible explanation relates to the product cycle model and the incorporation of services (Cusumano et al., 2007). According to this reasoning, firms need to provide highly differentiated and specialised services early in the product cycle to help lead users adopt new goods. When goods are more stable and established, firms can introduce standardised services to support large numbers of users and facilitate mass customisation strategies. If we accept that the low tech to high tech characterisation roughly maps onto the product cycle, we would expect the two ends of the scale to pursue service innovations more intensely. For high tech firms, the complexity of their products could be the driving force behind the offer of complementary services. In contrast, low tech firms are more likely to represent the most mature manufacturing industries, where service innovators are trying to achieve competitive advantages by offering new services to complement their traditional products. The result for low tech sectors may also indicate that manufacturing firms (with their high level of product and market knowledge) see opportunities for growth in downstream services that they do not find in their mature markets, a point made by Wise and Baumgartner (1999). Other explanations, however, related to the technology and market characteristics of the different sectors may exist.

The results for product innovations are coherent with previous evidence showing that the probability of achieving this type of innovation is greater in higher technology intensive sectors. The opposite is true for process innovations, which are negatively associated with high technology.

5. Discussion

Given the growing importance of servitisation in transforming manufacturing firms into more service like entities, this work analyses the process by which new services are generated by manufacturing firms. Specifically, the paper examines whether some factors traditionally associated with innovation in service firms ('service related' factors) may also have a positive impact on achieving service innovations in the manufacturing sector (RQ1). In addition, the study examines if these factors exert a differential effect on the achievement of product and process innovations in these manufacturing firms (RQ2). The empirical evidence obtained has allowed us to cast light on both of these research questions.

Training activities emerge as an important and differentiating determinant for service and product innovations. They are positively related to service innovations, but not to product innovations. In contrast, their effect on process innovations is positive and significant. This finding leads us to a series of conclusions.

First, and in line with the previous literature (Miles, 2001; Pires et al., 2008), investment in human resources plays a critical role in service innovations, particularly for the development of new skills in manufacturing firms involved in servitisation processes (Raja et al., 2010). Second, the significant effect that training activities exert on process but not product innovations leads us to qualify the empirical evidence obtained by previous research on the manufacturing sector (e.g., Walsworth and Verma, 2007). If this previous research had distinguished between product and service innovations (as is typical in CIS surveys), its results would probably have more precisely captured the determinants of the innovation process in manufacturing firms (firms that may also be innovating in services).

The use of advanced machinery, which is relevant to all types of innovation, is more important for service than for product innovations. This finding supports our research expectation that a traditional 'service related' factor such as advanced machinery and information technologies (Hipp and Grupp, 2005; Pires et al., 2008) will also be decisive for the achievement of service innovations in manufacturing firms. Furthermore, our finding on the significant impact of advanced machinery on product and process innovations highlights the relevance of our research model and the need to analyse product, process and service innovations together.

Collaboration with customers has a marked effect on the achievement of service innovations in manufacturing firms. Although this result was expected given that interaction with customers is a key feature of servitisation (Baines et al., 2009), it is surprising to observe that collaboration with this type of partner is not significant for the achievement of the other innovation outcomes. Once again, this finding reveals the need to analyse service, product and process innovations together in order to understand the innovation processes of servitised manufacturing firms better. Concerning the impact of the other technological partners, although competitors are also relevant partners for manufacturing firms to achieve service innovations, research organisations seem to have the biggest impact on product innovations in these firms.

This study also explores whether factors that typically lead manufacturing firms to achieve product and/or process innovations (i.e., 'manufacturing related' factors) will also exert an impact on the achievement of service innovations. On this point, the significant impact of R&D on service innovations is a somewhat unexpected but notable result. According to Gebauer et al. (2008), innovation in product related services can be integrated into the development process of new products. If, then, R&D is a critical factor to achieve product innovations in manufacturing firms, it should also exert a positive impact on service innovations in these firms. Indeed, our empirical models reveal a high correlation between product and service innovations. Therefore, the specific role exerted by external R&D on service innovations is worth noting. Our findings allow us to conclude that it is an even more important determinant of service innovation than it is of product innovation. We speculate that this could reflect the lack of expertise of manufacturing firms in developing new services, a factor that would make external sources of knowledge particularly useful. The positive impact of these 'manufacturing related' factors on service innovation can also be interpreted as evidence supporting the synthesis approach (Coombs and Miles, 2000). In other words, understanding how manufacturing firms achieve service innovations requires us to consider not only 'service related' factors but also the more traditional 'manufacturing related' inputs such as R&D or other partnerships beyond customers. This was the idea behind our research model, an idea supported by the empirical evidence.

Perhaps the greatest limitation of the present study has been our reliance on reports of introducing new or improved services, and our lack of detailed information on just what service innovations manufacturers are introducing. We would expect different types of product related (and other) service innovations to have different features and perhaps vary across manufacturing sectors (and firms of different size). We are aware that service innovation may be measured via more complex dimensions or scales than those used in this study (as suggested by den Hertog et al., 2010). The challenge awaiting future studies working with potentially richer information from other databases, then, is to improve the measurement of service innovation; such an improvement will make it possible to understand many aspects of service innovation more clearly. Collecting this information in a large scale survey is, of course, more costly than working with closed questions and responses, but such data would provide a great deal of enlightenment. With servitisation attracting so much attention as a factor in competitiveness, casting a little more light on its forms and antecedents would be no bad thing.

Even though the empirical analysis is limited to data from Spain, we feel that the conclusions are generalisable to other countries. Spain is a technologically advanced country whose industrial structure is similar to that of other countries in its environment (Eurostat, 2009). We believe that future research should take the results obtained in this study as a benchmark and proceed to compare their validity in other contexts with different industrial structures and levels of technology.

6. Conclusion

Servitisation of manufacturing firms is not a new phenomenon, but its growth and importance in different industries and countries make it a relevant topic for academic and management studies. This paper advances our knowledge of the antecedents of service innovation in manufacturing firms, an interesting topic that has received scant attention in the specialised literature.

Thus, this study analyses the impact of different factors traditionally linked to service innovation in the new context of manufacturing firms in order to gauge their impact on service innovations developed in these firms. In discussing the impact of these factors on the innovation processes of manufacturing firms and more specifically on the interrelation among different innovation outcomes, the paper contributes to the literature on service innovation, feeding into the synthesis approach (Coombs and Miles, 2000). This approach is based on the premise that some innovation factors may be important for achieving both new services and new products. To illustrate the research questions, the study contributes quantitative evidence on the antecedents of service innovations in manufacturing firms and on the different impacts of these factors on product and process innovation in these same firms.

The first conclusion worthy of note is the importance of 'service related' factors in service innovations in manufacturing firms. Employee training activities, the use of advanced technologies and close collaboration with customers all have positive impacts on service innovations in manufacturing firms. We should also note that some activities with low importance for innovation in service firms (such as R&D activities) do have a positive impact on the achievement of service innovations in manufacturing firms.

Additionally, the study examines whether such 'service related' factors exert a significant impact on product and/or process innovations in these manufacturing firms. The results show that the use of advanced technology also has a positive impact on product and process innovations in servitised firms, and that training activities are particularly important for achieving process innovations. These findings provide us with a better understanding of the antecedents of service innovations in servitised firms and highlight the need to analyse the determinants of service, product and process innovations together. Our large sample of manufacturing firms provides us with a

Table A1

Variable	Definition
Dependent variables	
SERVICE	Dichotomous variable. Takes value 1 if the firm declares that it has introduced new services.
PRODUCT	Dichotomous variable. Takes value 1 if the firm declares that it has introduced new goods.
PROCESS	Dichotomous variable. Takes value 1 if the firm declares that it has introduced new processes.
Independent variables	
TRAINING	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has trained his employees through internal or external training activities.
TECHNOLOGY	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has acquired machinery, advanced technology, hardware and software.
CUSTOMERS	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has engaged in technological collaboration with customers.
INT R&D	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has incurred internal R&D expenses.
EXT R&D	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has acquired external R&D services via contract, agreement, etc.
SUPPLIERS	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has engaged in technological collaboration with suppliers.
COMPETITORS	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has engaged in technological collaboration with competitors.
RESEARCH ORG	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has engaged in technological collaboration with research organisations (universities, technology institutes, etc.).
MARKET	Dichotomous variable (lagged 2 periods). Takes value 1 if the firm declares that it has performed activities related to market prospecting.
Control variables	
INN EFFORT	Quantitative variable. Measured as the logarithm of the total innovation expenses.
SIZE	Quantitative variable. Measured as the logarithm of sales.
GROUP	Dichotomous variable. Takes value 1 if the firm belongs to a group of companies.
FOREIGN OWN	Dichotomous variable. Takes value 1 if more than 50 percent of the firm's equity is foreign owned.
EU MK	Dichotomous variable. Takes value 1 if the firm is selling its products in the European Union (EU) market.
OVERSEAS MK	Dichotomous variable. Takes value 1 if the firm is selling its products in foreign markets outside the EU.
LT	Dichotomous variable. Takes value 1 if the firm belongs to a low tech sector according to the OECD's classification (2005). This is the reference category.
MLT	Dichotomous variable. Takes value 1 if the firm belongs to a medium-low tech sector according to the OECD's classification (2005).
MHT	Dichotomous variable. Takes value 1 if the firm belongs to a medium-high tech sector according to the OECD's classification (2005).
HT	Dichotomous variable. Takes value 1 if the firm belongs to a high-tech sector according to the OECD's classification (2005).

comparable context with which to analyse the antecedents of the three types of innovations and qualify the results from previous research of manufacturing sectors that does not take the phenomenon of servitisation into account. Future research should include findings on the interrelation among these three types of innovations.

These conclusions also have implications for management. As our analysis reveals, servitisation is common in many manufacturing industries. Managers, then, need to realise that a good way of enhancing the competitive position of their products is to complement their offer with services that add value to their products and satisfy more complex customer demands. In this way our findings make it possible to offer some recommendations for manufacturing firms looking to develop service innovations, along with the already common product and process innovations. 'Service related' factors exist that are fundamental for the development of new services in manufacturing firms. Moreover, managers should not neglect those activities that are traditionally less associated with service innovations, such as R&D activities.

This last point relates to a conclusion that could have practical relevance and act as a spur to further empirical research. Running in parallel to the suggestion that manufacturing firms lack a tradition of service innovation is the idea that firms developing new services are less well linked to innovation systems or that there are less developed innovation systems for them to link to than those pursuing more conventional manufacturing innovations. These speculations merit further attention; analyses could be performed via a study of CIS data for more countries (and periods), as well as via case studies and qualitative research.

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Appendix

See Table A1.

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