ECONOMICS OF INNOVATION AND NEW TECHNOLOGY, 2015
http://dx.doi.org/10.1080/10438599.2015.1073478

Technological and non-technological innovation and productivity in services vis-à-vis manufacturing sectors

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ABSTRACT

In this paper, the links between investment in innovation activities, innovation outputs (technological and non-technological innovation) and productivity in services vis-à-vis the manufacturing sector are explored using innovation survey data from Uruguay. The size of firms, their cooperation in R&D activities, the use of public financial support, patent protection and the use of market sources of information are very important drivers of the decision to invest in innovation activities across sectors. The main determinants of technological and non-technological innovations are the level of investment in innovation activities and the size of the firm. The results indicate that both technological and non-technological innovations are positively associated to productivity gains in services, but non-technological innovations have a more important role. The reverse happens for manufacturing, where technological innovations are more relevant for productivity.

ARTICLE HISTORY
Received 3 October 2014
Accepted 3 July 2015

KEYWORDS
Innovation; productivity; services; manufacturing; innovation surveys; Latin America

JEL CLASSIFICATION
O12; O14; O31; O33; O40

1. Introduction

Evidence from industrialized countries suggests that investing in innovation activities can boost productivity growth (OECD 2005, 2009b, 2009c, 2010; Cainelli, Evangelista, and Savona 2006; Rubalcaba and Gago 2006; Gallouj and Savona 2008; Gallouj and Djellal 2010; Uppenberg and Strauss 2010; Europe Innova 2011; Crespi and Zuñiga 2012). However, there are only a few studies comparing the effects of different types of innovation in productivity in services with those in manufacturing and even fewer for developing countries (see next section for a brief review of this literature). This study aims to fill this gap by understanding the determinants of technological (product or process) and non-technological (organizational or marketing) innovation and their impact on productivity in the services sector vis-à-vis manufacturing in one Latin American and the Caribbean (LAC) country, Uruguay.[1]

Current innovation policies in developing countries are biased towards manufacturing and give limited attention to non-technological innovation. Thus, developing policies and programmes to support innovation requires a better understanding of the drivers and the effects of both technological and non-technological innovation. Taking as given that business practices related to innovation are different in services sectors than in manufacturing, proper support and encouragement for innovation and productivity growth in the services sector may need different and new policy designs and programmes. This motivates the comparative perspective, with respect to the manufacturing sector, of this paper. Furthermore, given that non-technological and technological innovation is linked to

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each other, it becomes of primary importance to analyse their determinants, how they interact and how they affect firm performance in the services and in the manufacturing sector.

In addition, the study also shows results for small firms. This is justified not only by the importance of small firms in the services sector (Tacsir 2011), especially in LAC countries, but also because large firms are in a better position to carry out research and innovate with little external support. Among the advantages cited for large firms are a larger spread of fixed costs over greater output, economies of scope and better appropriation of external knowledge spillovers (Cohen and Levinthal 1989; Crespi and Zuñiga 2012). Small firms have different characteristics and needs that justify a special focus on them. Small firms are less likely to innovate and they innovate differently: instead of R&D activities, they follow different strategies that combine organizational innovation, purchase of equipment and learning through interaction with clients, and they also face different competitive challenges (European Commission 2010).

Finally, the paper analyses both Knowledge-Intensive Business Services (KIBS) and Non-KIBS services and compares them with the high- and low-tech manufacturing sectors. Even though Non-KIBS services tend to be less innovative than KIBS, this is a very important subsector to be analysed, not only because of its weight in terms of value added and employment, but also because some of the most vulnerable workers (female, young, less educated and less-formalized workers) are employed there. Therefore, understanding how innovation and productivity gains happen in this sector can have a potential impact on the design of more focused innovation policies with a better positive impact on productivity and labour market and social indicators.

Against this background, the paper uses a modified version of the model of Crépon, Duguet, and Mairesse (1998) (CDM) and Uruguayan data. We extend the CDM framework to include both technological and non-technological innovation, and total expenditure on innovation activities (besides R&D). This is one of the first comparative (with manufacturing) micro-econometric analyses of the links between innovation activities, technological and non-technological innovation, and productivity in the services sector.[2]

The rest of the paper is organized as follows. The next section presents a brief review of the literature. Section 3 describes the data. Section 4 presents the empirical strategy and in Section 5 the results are analysed. Section 6 shows the heterogeneities across different groups of services and manufacturing firms. Finally, Section 7 concludes.

2. Innovation in services and the available evidence

There is an ongoing debate about the approach that must be used to study innovation in services (Gallouj and Weinstein 1997; Gallouj and Savona 2010). One of the approaches, the assimilation approach, implicitly assumes that innovation in services can be assimilated into innovation in goods and in the manufacturing sector. Therefore the same conceptual framework can be used for analysing innovation (mostly technological) in manufacturing and the same instruments, for instance community innovation survey (CIS)-like[3] innovation surveys, are appropriate for the study of service innovation (Miozzo and Soete 2001). This can be contrasted with authors who argue that services are particular enough to deserve a whole set of new concepts, a new framework and new instruments (Djellal and Gallouj 2000; Tether and Howells 2007). This second approach is the so-called demarcation approach.

At the base of this discussion are the things that make goods and services similar or not and also the similarities and differences in the process of innovation. Services are more about doing useful things rather than making useful goods, and making useful changes in people or things as opposed to selling goods for users to make their own changes with (Miles 2012). Of course these differences also imply that the ‘technologies’ to generate services and goods are in general different (for example, services are more labour intensive), and that the way of innovating could also be different (e.g. for some services, non-technological innovations, like marketing and organizational change, can be more important than technological ones). Also, service innovation is generated in a more ad hoc way, depending less on formal R&D and more on the contact with customers. These characteristics, together with the intangibility and the simultaneity of production and consumption of services, make it much more difficult to identify service innovations than innovations in goods, and this is one of the reasons why traditional CIS-like innovation surveys may not be the best instrument to identify and analyse innovation in services.

As a result of this debate, a third approach emerged, the so-called synthesis or integrated approach (e.g. Castellacci 2008; Peneder 2010). This approach, while recognizing differences between services and manufacturing and their different emphasis on technological or non-technological innovations, along with other specificities of service innovation, also recognizes the need for integrating the knowledge accumulated from manufacturing with the new knowledge currently being generated for services and service innovation. Moreover, some authors claim that because of the increasingly blurred boundaries between manufacturing and services, this is a more appropriate approach to study innovation (Bryson 2010). From a value chain or value system perspective, this also seems to be the right approach to study innovation.

This study can be placed within the integrated approach. Even though we use in our analysis a model originally developed and used for analysing the R&D impact on productivity in manufacturing and CIS-like survey data, our interest and our empirical strategy is designed to shed light, as far as possible with this model and these data, on the heterogeneities and similarities of innovation in services and manufacturing and their impacts on productivity. In particular, we explore the determinants of both technological and non-technological innovations and their differential impact on productivity across sectors.

The CDM model has been estimated with firm data from innovation surveys mostly for European and OECD countries and for the manufacturing sector. These studies have mainly analysed product innovation, but recently also process innovation has been included in the analysis. Studies differ according to the way of modelling the interaction between types of innovation, the use of quantitative or qualitative innovation indicators and the econometric methods used to account for simultaneity and selectivity. These studies are mainly for the manufacturing sector. A recent review of this literature (Hall 2011) finds that the evidence on the (positive) impact of product innovation on revenue productivity is strong but the impact of process innovation is somewhat ambiguous.

There are only a few studies assessing empirically the relation between innovation and productivity in the service sector using firm-level data, and even fewer comparing services and manufacturing. In what follows we briefly review this literature.

Cainelli, Evangelista, and Savona (2006) explore the two-way relationship between innovation (different proxies are used) and economic performance (labour productivity, measured as sales per worker, is one of the indicators) in services at the firm level. They use longitudinal firm-level data for Italy (735 service firms with 20 or more employees), that are obtained from the matching of the Italian CIS II data (1993–1995) and a set of economic variables from the Italian System of the Enterprise Accounts (1993–1998). Heckit models are used to estimate the impact of innovation on productivity and vice versa, and exploit the different timing of the variables to deal with endogeneity issues. Their main results are: (i) innovation activities undertaken in 1995 do have a positive impact on productivity levels in the following three years, (ii) better performing firms are more prone to innovate as well as to devote more resources to innovation, (iii) estimates reveal the presence of a cumulative mechanism which dynamically links productivity and total innovation expenditure per employee.

Lööf (2005) brings a comparative perspective into the relationship between innovation and productivity in manufacturing and services. He investigates whether there is any evidence for the notion that service industries have a lower propensity to be innovative or whether they are less efficient in deriving benefits from innovations. Matched firm-level data from Sweden CIS for the year 1999 and data collected from Statistics Sweden are used in the empirical exercise. A version of the CDM model is fitted for two samples of knowledge-intensive firms: 607 knowledge-manufacturing firms (with high degree of R&D intensity) and 538 business service firms. The labour productivity is measured as value added per employee and innovation is proxied by the ratio of innovation sales to total sales. Lööf finds a consistent positive relationship between R&D, innovation and productivity for both samples of firms. The estimated coefficients are similar for both samples.

Mairesse and Robin (2010) analyse the link between innovation and productivity using CIS data for French Manufacturing and Services. They study the evolution of the innovation–productivity relationship in the French manufacturing industry over two periods of time (1998–2000 and 2002–2004) and compare this relationship in the manufacturing and services industries in the period 2002–2004. The service sample comprises 3599 firms from CIS4 (with 20 or more employees), and the manufacturing one consists of a sample of 3524 firms from CIS3 and a sample of 4955 firms from CIS4. They estimate a version of the CDM model. They use the (log of) labour productivity (measured as the ratio of value-added to the number of employees) as the main dependent variable, and indicators of product and process innovation, as proxies of innovation. They find a significant effect of product innovation on productivity and no effect (or little effect) of process innovation. This result is consistent across both periods and for both manufacturing and services. Being a product innovator results in a 17% increase in the log of labour productivity (with a standard deviation of 3%). This increase is stronger in services than in the manufacturing sample (13%), which suggests that product innovation results in a greater differentiation between services firms.

Lopes and Godinho (2005) analyse the link between innovation and labour productivity in services with a CDM model and using the second Portuguese CIS (1995–1997) that have 1014 observations. They find a positive effect of innovation output on productivity, but a negative effect of innovation intensity.

Stelios and Aristotelis (2008) explore the relationship between innovation output (sales from innovations per employee) and productivity (sales per employee) in the service sector in Greece. They use data from the CIS 2 (1994–1997) for Greece (301 observations). They conclude that an increase in the innovation output leads to an improvement in productivity, both for the whole sample and for KIS.

Masso and Vahter (2012) using a version of the CDM model and CIS data for Estonia for the period 2002–2004 (604 firms) and 2004–2006 (687 firms) find that innovation is associated with increased productivity (log sales per employee and log value added per employee) in the service sector, and that the effect is stronger in the less knowledge-intensive firms. Non-technological innovations (marketing and organizational) play less important role than technological innovations (product and process).

Criscuolo (2009), in a large-scale study based on the CDM approach and CIS data, shows that for most countries (8 of 10)[4] the productivity effect of product innovation was larger in the manufacturing sector than in services.

Finally, Segarra-Blasco (2010) using a CDM model shows that labour productivity was directly affected by R&D intensity and product innovation in both services and manufacturing firms in Catalonia using CIS data for the 2002–2004 period. Furthermore, both internal R&D and external R&D acquisition affect productivity in the manufacturing and service industries (Segarra-Blasco and Teruel 2011).

3. Data and descriptive statistics

The services sector is one of the major contributors to output and employment in Uruguay. In the 2004–2009 period, it has represented approximately 60% of the gross domestic output (GDP) of the economy and employed more than 70% of the total workforce. During this period of intense dynamism of the economy (which has grown at an annual rate of 6.2%), the rate of growth of the sector has been even higher (7% average annual growth rate).

Both the employment and the output of the services sector originate mainly from a few subsectors. Half the GDP of the sector is explained by three subsectors: ‘retail’, ‘communications’ and ‘real estate, renting and business services’. The same applies to employment, where two sectors account for 50% of total employment in services: ‘retail’ and ‘professional services and household services’.

Innovation surveys in Uruguay do not cover the universe of the services sector. However, the weight of the subsectors considered here is significant in terms of output and employment, representing more than 50% of the output and 33% of the employment of the sector.

The subsectors covered by the service innovation survey (SIS) were chosen by the Uruguayan National Agency for Research and Innovation, following two criteria. First, knowledge-intensive services were well represented in the sample, in particular, the high technology ones: knowledge-intensive market services, and other knowledge-intensive services. Second, the selection sought to include subsectors considered important for the economic development of the country, such as the tourism-related ones.

The two available waves of the Uruguayan services innovation survey[5] are considered here: 2004–2006 and 2007–2009. Both surveys have been matched with the EAS[6] in 2004 and 2007 because we needed information on capital (fixed assets) at the firm level. In order to avoid endogeneity problems associated with the capital variable, we use this variable at the beginning of the period of the survey.[7] All the other variables used in the empirical exercise come from the services innovation surveys (see Table A2 in the Appendix for a complete description of the variables).

In order to compare results with the manufacturing sector, we replicate the exercise using two waves of the manufacturing innovation survey (2004–2006 and 2007–2009) matched with the annual EAS.[8]

Table 1 shows descriptive statistics for the services and manufacturing sectors (see also additional descriptive statistics for the variables included in the regressions in Appendix). As the first panel of

Table 1. Descriptive statistics.

	N	Services 1868	Small 1133	Manufacturing 1727	Small 1037
Innovation behaviour of firms (share of firms)					
Tech. innovation	Product	0.183	0.144	0.234	0.159
	Process	0.242	0.186	0.325	0.220
	Tech innovation (1)	0.307	0.238	0.380	0.263
Non-tech innovation	Organizational	0.203	0.142	0.166	0.103
	Marketing	0.094	0.071	0.085	0.047
	Non-tech innovation (2)	0.244	0.176	0.204	0.134
	Any innovation (3)	0.398	0.314	0.430	0.303
	Tech and on-tech innovation (4)	0.152	0.100	0.153	0.095
Inputs and outputs from innovation					
Inputs	Innovation expenditures (5)	1.71	1.64	1.90	1.44
	R&D (6)	11.24	11.31	12.01	13.53
	Machinery acquisition (7)	27.03	22.17	47.04	42.65
	Other innovation activities (8)	61.74	66.53	40.95	43.82
	Firms that performed R&D	10.65	7.24	15.98	9.55
	Firms that performed R&D on a continuous basis	13.97	8.74	33.82	19.09
Outputs	Turnover from product innovations (9)	11.35	9.32	11.25	7.86
	Turnover from new to market product innovations	4.27	3.15	4.26	2.77
Policy related variables					
International markets (10)		0.067	0.071	0.175	0.090
Co-operated with clients, providers (11)		0.912	0.914	0.929	0.930
Co-operated in R&D (12)		0.136	0.100	0.136	0.073
Co-operated with universities or government (13)		0.031	0.023	0.067	0.037
Public support (14)		0.021	0.016	0.042	0.023
Applied for patents (15)		0.013	0.008	0.023	0.014

Notes: (1) Product or process innovation, (2) organization or marketing innovation, (3) technological or non-technological innovation, (4) technological and non-technological innovation, (5) total expenditures on innovation (as a percentage of total turnover), (6) expenditures on R&D (internal) as a percentage of total expenditures on innovation, (7) expenditures on machinery acquisition as a percentage of total expenditure on innovation, (8) expenditures on the rest of innovation activities as a percentage of total expenditures on innovation, (9) share of product innovation in turnover, (10) share of firms that export, (11) share of firms that co-operated with clients or providers, (12) share of firms that co-operated in R&D on innovation activities, (13) share of firms that co-operated with universities/higher education or government research institutes, (14) share of firms that received public financial support for innovation and (15) share of firms that applied for one or more patents.
Source: Authors' own calculations.

Table 1 shows, 40% of the services sector firms innovate. This figure is 43% for the manufacturing sector. The biggest heterogeneity between manufacturing and services in terms of innovation comes from technological innovation (defined as process or product innovation). 38% of the firms in the manufacturing sector report technological innovation, as compared to 31% in the services sector. Meanwhile, the non-technological innovation propensity is 24% for services versus 20% in manufacturing. One interesting fact is that 37% (35%) of the firms in the services (manufacturing) sector that do any type of innovation engage in both technological and non-technological innovation. A simple mean test on the share of firms doing technological or non-technological innovation shows that the share of firms doing technological innovation is significantly higher in manufacturing with respect to services, while the share of firms that perform non-technological is significantly higher in the service sector.[9]

The second panel of Table 1 shows that innovation expenditures as a percentage of turnover are 1.7 in the services sector versus 1.9 in manufacturing, 11% (12%) of this spending is invested on R&D in the services (manufacturing) sector, while 27% (47%) is for acquisition of machinery in services (manufacturing).

The third panel of Table 1 shows some additional comparative statistics. Some important heterogeneities between services and manufacturing stand out in the table. To start with, we find almost three times more firms exporting in the manufacturing than in the services sector. While the cooperation with clients and providers and in R&D seems to be similar between the two sectors, cooperation with universities is more than twice in manufacturing than in the services sector. The share of firms that receive public financial support is twice in manufacturing than in the services sector. The patent behaviour clearly differs between the two sectors. Firms in the manufacturing sector show a higher propensity to apply for patents than services firms.

4. Empirical strategy

The strategy used in this paper is a modified version of the model developed by Crépon, Duguet, and Mairesse (1998) – the CDM model – , which offers a method to empirically estimate the innovation–productivity link with a recursive model.[10] The model consists of a system of four non-linear equations: (1) the decision of the firm to engage in innovation activities, (2) the decision of the firm on how much to invest in innovation activities (innovation expenditures per worker), (3) the knowledge or innovation production function (innovation output) and (4) the productivity equation.

The CDM model intends to deal with the problem of selection bias[11] and endogeneity in the innovation and productivity functions.[12]

The endogeneity problem is solved by dividing the innovation–productivity relationship into three stages – innovation input, innovation output and productivity– and making the results of each one of the stages an endogenous variable to the following one. Thus, innovation expenditure is an endogenous variable to the innovation equations, and innovation is an endogenous variable to the productivity equation.

In the first stage, a Heckman model will be estimated to correct for the selection bias. The innovation activities stage explains the behaviour of firms in two complementary ways. The first one accounts for the determinants of the decision to engage in innovation activities (Equation (1)), and the second one for the level of expenditure or investment in innovation activities (Equation (2)).

The *innovation decision* equation could be expressed as follows:

$$\begin{aligned} \mathrm{ID}_i &= 1 \quad \text{if} \quad w_i\alpha + \varepsilon_i > c \\ \mathrm{ID}_i &= 0 \quad \text{if} \quad w_i\alpha + \varepsilon_i \le c, \end{aligned} \tag{1}$$

where ID_i is the binary innovation decision variable which takes a value of 1 for firms that decide to innovate and 0 for firms that do not, w is the vector of explanatory variables that determine the decision, α is the vector of parameters, ε is the error term and c is the threshold level that determines whether the firms decide to invest in innovation or not.

The vector of explanatory variables is composed by the firm's number of employees (size), a dummy indicating whether the firm is an exporter, a dummy indicating whether more than 10% of the capital of the firm is foreign-owned, a dummy indicating whether the firm applied for patent protection, dummy variables indicating whether the firm received public financial support for innovation activities, whether the firm cooperated with other firms to carry out R&D activities, whether the firm considers market, scientific or public sources of information important for the innovation activities and finally whether the firm perceives that there are meso-economic (for example at the sectoral level) credit restrictions. Industry dummies are also included in regressions. The justification for the inclusion of size at this stage is that if there are fixed costs of innovation (e.g. the cost of installing R&D labs), larger firms can better diffuse these costs across a larger total amount of activity and therefore are more likely to invest in innovation activities.

The second equation is derived from an equation that accounts for the magnitude or intensity of innovation activities carried out by firms. The equation for the *innovation effort (or expenditure)* would be

$$\begin{aligned} \mathrm{IE}_i &= z_i\beta + e_i \quad \text{if} \quad \mathrm{ID}_i = 1 \\ \mathrm{IE}_i &= 0 \qquad\qquad \text{if} \quad \mathrm{ID}_i = 0, \end{aligned} \tag{2}$$

where IE is the magnitude of the innovation effort (the log of innovation expenditures per employee in our case), z is the vector of explanatory variables, β is the vector of parameters and e is the disturbance. As for the explanatory variables, we make the assumption that the variables that affect the process of decision-making can potentially also determine the magnitude of innovation expenditures,[13] but because we are using innovation expenditures per employee, the variable size (number of employees) is not included in the second equation (this exclusion will also allow the identification of the first equation without exclusively relying on the functional form of the model). Implicitly, since our dependent variable is innovation expenditures per employee, we are assuming that the innovation expenditures variable is strictly proportional to size (the number of employees).

The second stage is the knowledge production (or innovation output) function. We extend the CDM model to have two different equations, one for technological innovations and one for non-technological innovations. Here, 'technological innovation' (product or process innovation) and 'non-technological innovation' (organizational or marketing innovation) are dependent (dummy) variables that are used as a proxy for innovation output. The *innovation output* equations or *knowledge production functions* are

$$\begin{pmatrix} \mathrm{TI}_i \\ \mathrm{NTI}_i \end{pmatrix} = \widehat{\mathrm{IE}}_1\gamma + x_i\delta + u_i, \tag{3}$$

where TI is a dummy indicating technological innovation (product or process innovation) and NTI is a dummy for non-technological innovation (organizational or marketing innovation), IE is the endogenous explanatory variable that results from Equation (2) (we use its predicted value $\widehat{\mathrm{IE}}_1$), γ is a diagonal matrix of parameters, δ is block diagonal matrix of parameters, x is a block diagonal matrix of determinants of innovation output and u is the error vector.

The innovation output is explained by the magnitude of the innovation activity – predicted from the Equation (2) in the previous stage – and by a set of exogenous variables which are the same ones included in the first stage with the exception of the public financial support variable. This implies that public financial support does not affect innovation output directly, but only indirectly through the level of innovation activities (*proxied* by log innovation expenditures per employee).

A bivariate probit model is estimated in this stage, instead of a linear model to take into account the correlation between the two types of innovation. We are assuming that the errors of both equations follow a bivariate normal distribution, thereby allowing for correlation between them.

The third stage is the productivity equation. For the productivity equation, CDM takes a Cobb–Douglas production function with physical capital, employment and innovation outputs (or alternatively, innovation expenditures). For this equation, log transformations are used, resulting in

$$y_i = c + \pi_1 k_i + \pi_2 l_i + \pi_3 \widehat{\mathrm{TI}}_I + \pi_4 \widehat{\mathrm{NTI}}_I + v_i, \tag{4}$$

where y_i is the log of output per worker (sales per worker in our estimations) – labour productivity , c is a constant, k_i is the log of physical capital per worker, l_i is the number of workers (our variable size), and $\widehat{\mathrm{NTI}}_I$ are the predicted innovation outputs that results from Equation (3), π_1 to π_4 are parameters and v_i is a disturbance term. This equation is estimated using ordinary least squares, including industry dummies.

As an alternative and a robustness check to (4), we will estimate an equation using as a proxy of innovation the predicted innovation expenditure ($\widehat{\mathrm{IE}}_I$):

$$y_i = c + \pi_1 k_i + \pi_2 l_i + \pi_5 \widehat{\mathrm{IE}}_I + \xi_i. \tag{4'}$$

Before ending the section, it is important to note that we have extended the original CDM model in three ways. First, R&D is less relevant when describing innovation in the service sector. Therefore, R&D is substituted by a more general investment in innovation activities variable, including investment in design, installation of machinery, industrial engineering, embodied and disembodied technology, marketing and training (all of which are innovation expenditures). Second, and most importantly, we extend this model by changing the estimation strategy of the innovation output equation, Equation (3), to adapt it to the services sector where non-technological innovations are very important. We distinguish between technological innovations (product and process) and non-technological ones (organizational and marketing innovations), and we estimate them simultaneously using a bivariate probit approach.[14] Finally, as distinct from other previous studies (e.g. OECD 2009a) and following Crespi and Zuñiga (2012), we estimate the CDM model not only for innovative firms, but for all firms. That is, we estimate Equations (1) and (2) based on reported innovation activities investment and use predicted values for all firms to proxy innovation effort in the knowledge production function. Equations (3) and (4) are also estimated for all firms.

5. Main results

The section is dedicated to presenting the findings from estimating the modified version of the CDM model presented in Section 4. The model is estimated for the services sector and manufacturing firms with data from Uruguay. Results for small firms in both sectors are also analysed (small firms are defined as those with fewer than 50 employees).

5.1. *Innovation activities*

Table 2 presents the findings from the first stage of the CDM model. The selection equation for engaging in innovation activities is shown in the left panel. The right panel of the table shows the results of estimating an investment intensity equation, conditional on the decision to innovate.

This stage shows that the determinants for performing innovation (left panel) are very similar in the manufacturing and services sector. The use of measures of formal protection (patents applied for) and the receipt of public funding are positively related to firms' decisions to invest in innovation activities, except for small firms in the manufacturing sector. However, when considering the entire sample, the coefficient of the patent protection variable is bigger for manufacturing, which supports our initial hypothesis that this instrument is more important for manufacturing than for services, which use alternative methods of protection such as trademarks, copyrights. Larger exposure to international competition, as measured by the export orientation of the firm, is associated with a higher probability of investing in innovation only for services firms. Therefore,

Table 2. Innovation expenditure equation.

	Services		Manufacturing		Services		Manufacturing	
	All	Small	All	Small	All	Small	All	Small
Variable\dep. var.	Probability of investing in innovation IE > 0				Log (Innovation expenditure) = Log IE			
Exporter	0.375***	0.300***	0.0709	0.135	0.518	0.210	0.159	0.257
	(0.0861)	(0.108)	(0.0642)	(0.119)	(0.323)	(0.385)	(0.106)	(0.216)
Foreign-owned	0.141	0.305	0.0922	0.220	0.570**	0.629**	0.0297	0.273
	(0.126)	(0.219)	(0.131)	(0.218)	(0.224)	(0.306)	(0.139)	(0.351)
Patent protection	1.491***	0.883**	1.884***	8.003	0.503**	0.0889	−0.383	0.523
	(0.329)	(0.425)	(0.525)	(222,785)	(0.245)	(0.596)	(0.349)	(0.497)
Public support	1.984***	2.060***	2.182***	13.80	0.994	0.743	0.649***	1.070**
	(0.413)	(0.463)	(0.506)	(46,389)	(0.660)	(0.519)	(0.247)	(0.469)
Cooperation in R&D	1.282***	1.759***	1.525***	1.574***	1.001***	0.792	0.525***	1.079***
	(0.175)	(0.325)	(0.207)	(0.325)	(0.337)	(0.539)	(0.165)	(0.356)
Market information sources (Info1)	0.520***	0.312***	0.377***	0.236*	0.367	0.104	0.291	0.261
	(0.0944)	(0.103)	(0.108)	(0.133)	(0.299)	(0.546)	(0.203)	(0.301)
Scientific sources (Info2)	−0.140	−0.0476	−0.259***	−0.381***	0.0410	−0.115	−0.0193	−0.206
	(0.121)	(0.0730)	(0.0980)	(0.120)	(0.173)	(0.160)	(0.207)	(0.236)
Public sources (Info3)	0.00993	0.221*	0.118	0.229**	0.356***	0.422	0.0846	−0.0249
	(0.0902)	(0.121)	(0.105)	(0.113)	(0.0650)	(0.257)	(0.112)	(0.233)
Size	0.248***	0.254***	0.372***	0.443***				
	(0.0216)	(0.0697)	(0.0247)	(0.0711)				
Constant	−1.789***	−1.979***	−2.109***	−2.313***	−0.0637	1.161	2.219***	1.651**
	(0.0626)	(0.215)	(0.129)	(0.309)	(0.565)	(1.231)	(0.336)	(0.664)
Number of observations	1868	1133	1727	1037	1868	1133	1727	1037
Censored observations	1149	796	996	727	1149	796	996	727
Log likelihood					1433	−1215	−2273	−1061
Dependence (ρ)					0.578**	0.111	−0.0822	0.242
					(0.227)	(0.398)	(0.112)	(0.206)

Note: All regressions include industry dummies. Errors clustered at two digit industry level.
*Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level.

competition in international markets seems to act as an incentive to innovation. Cooperation in R&D and market sources of information are associated with higher probability of investing in innovation activities. The positive effect of cooperation in R&D points to the existence of economies of scale and scope in the production of knowledge. Meanwhile, the information coming from the markets seems to be important for the investment decision. Scientific sources of information seem to have negative or no effect. While the impact of public sources of information is not important when using the whole sample, the impact appears to be relevant for services and among small firms.

Finally, larger firm size is associated with an increased probability of investing in innovation inputs. This offers support for the hypothesis that economies of scale (and fixed costs) are present in the production of knowledge. Moreover, size is more relevant for manufacturing than for services. The coefficient for manufacturing is 50% larger than for services. A possible explanation for this finding is that services require less R&D and less formal processes to innovate and therefore are less subject to economies of scale.

Having controlled for selection bias, we then make use of the assumption that the investment expenditures function is linear in size. Note that the dependent variable is expenditures per employee of the firm (number of employees is our proxy for size).

The determinants of the decision of how much to invest in innovation activities differ across sectors. The exposure to international markets has no effect on the level of investment in innovation for both sectors. While being foreign-owned, patent protection is only important in the service sector. Instead, public financial support seems to affect positively the size of the investment only in the manufacturing sector. Cooperation in R&D continues to be important for both sectors in terms of the level of the investment. Public sources of information have a positive effect only in the case of services and taking the whole sample into account. Scientific sources and market sources of information have no effect on the level of investment.

It is interesting to note that there are many factors which are relevant for the decision to invest, but are not relevant for the amount invested in innovation activities by firms. In particular, the only two determinants that seem to be important in the manufacturing subsample are cooperation in R&D and public support; foreign ownership, however, stands out as the only factor found to be significant when explaining investment decisions.

5.2. *Knowledge production function*

Table 3 outlines the results of the estimation of the knowledge production function, with dummy variables for technological and non-technological innovation used as dependent variables. The coefficients in the table show marginal effects of explanatory variables, estimated at the sample means.

The results, as hypothesized, indicate that innovation output is determined significantly and positively by the level of investments in innovation inputs, in both services and manufacturing sectors, and for all firm sizes. The predicted values for innovation investments are obtained from the previous stage of the CDM model – the innovation expenditure equation (stage 1 above).

We find that in the case of technological innovation, the effects of innovation expenditures are larger than those for non-technological innovation. It has been argued in the literature that product innovations are more linked to the technology used and could be more likely to result from formal and internalized R&D activities (Musolesi and Huiban 2010) that require more investment. This could explain the higher correlation of innovation expenditures with technological innovation in our results.

Results also show that the effects of innovation expenditures are stronger in the manufacturing sector, probably because manufacturing requires more 'explicit' innovation expenditures to generate

Table 3. Knowledge production function innovation output.

	Services		Manufacturing		Services		Manufacturing	
	All	Small	All	Small	All	Small	All	Small
Variable\dep. var.	Technological innovation				Non-technological innovation			
Exporter	−0.363	0.00257	−0.253**	−0.300	0.111	0.00536	−0.236***	−0.560***
	(0.230)	(0.182)	(0.0989)	(0.204)	(0.0928)	(0.137)	(0.0822)	(0.132)
Foreign-owned	−0.878***	−0.935**	−0.116	−0.595***	0.105	−0.0558	−0.0591	−0.226
	(0.216)	(0.376)	(0.131)	(0.181)	(0.113)	(0.356)	(0.117)	(0.252)
Patent protection	0.517**	0.804*	2.060***	0.450	0.413	0.349	1.001***	0.435
	(0.215)	(0.422)	(0.327)	(0.417)	(0.400)	(0.406)	(0.155)	(0.278)
Cooperation in R&D	−0.142	0.0410	0.183	−0.518	0.368**	0.552	0.165	−0.775**
	(0.302)	(0.335)	(0.230)	(0.572)	(0.182)	(0.485)	(0.161)	(0.326)
Market information sources (Info1)	0.00295	0.359***	−0.261*	−0.0948	0.508***	0.252	0.0413	−0.329*
	(0.101)	(0.0799)	(0.152)	(0.185)	(0.105)	(0.179)	(0.150)	(0.186)
Scientific sources (Info2)	−0.194**	0.0560	−0.235**	−0.0190	−0.0397	0.218**	−0.0579	0.104
	(0.0890)	(0.0799)	(0.113)	(0.186)	(0.0675)	(0.0919)	(0.0616)	(0.168)
Public sources (info3)	−0.456***	−0.434*	0.0214	0.367***	−0.114	−0.210	0.244**	0.462**
	(0.163)	(0.251)	(0.0948)	(0.101)	(0.122)	(0.251)	(0.122)	(0.209)
Size	0.196***	0.215**	0.346***	0.392***	0.227***	0.247***	0.309***	0.331***
	(0.0260)	(0.0850)	(0.0318)	(0.0897)	(0.0194)	(0.0675)	(0.0300)	(0.0673)
Predicted log IE	1.387***	1.548***	2.332***	1.684***	0.399**	0.777	0.649***	1.220***
	(0.293)	(0.487)	(0.333)	(0.366)	(0.197)	(0.544)	(0.240)	(0.249)
Constant	−1.682***	−3.898***	−7.578***	−5.242***	−2.391***	−3.307***	−3.898***	−4.586***
	(0.145)	(0.462)	(0.753)	(0.693)	(0.0566)	(0.734)	(0.569)	(0.434)
Number of observations	1868	1133	1727	1037	1868	1133	1727	1037
Log likelihood					−1809	−974.8	−1587	−790.2
Independence (rho)					0.563***	0.574***	0.533***	0.630***
					(0.0310)	(0.0280)	(0.0399)	(0.0669)

Note: All regressions include industry dummies errors clustered at two digit industry level.
*Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level

innovations. Meanwhile the coefficient of the innovation expenditures variable is not statistically different from zero for non-technological innovation in small services firms. Non-technological innovation probably requires innovation activities that are less dependent on the amount invested by the firm, since they are obtained in a less-formalized and more ad hoc process (e.g. learning from the contact with clients).

Additionally, we find that size is a very important determinant of the probability of undertaking technological and non-technological innovation in both sectors. This is an expected result; larger firms have the advantage of spreading fixed costs (e.g. R&D lab costs) over greater output, they have economies of scope, and they can better appropriate external knowledge spillovers (Cohen and Levinthal 1989; Crespi and Zuñiga 2012).

Formal protection, as measured by number of applications for patents, has a positive and significant effect on technological innovation, as expected. While this is true also in the whole sample for the manufacturing sector for non-technological innovation, in the services sector it has no significant effect. Thus, the effect of patent protection seems to be stronger in the manufacturing sector than in the services sector. This does not mean that formal protection is irrelevant for services, if we take into account that services use more other types of protection, such as design, copyrights and trademarks that unfortunately are not captured by the Uruguayan innovation survey.

Results indicate that in general the information sources do not have a significant impact beyond the effect that they have through the innovation expenditure. Moreover, some of the sources have been found to have a negative impact. The only source that has a positive effect is the information based on the market (clients, suppliers, etc.) in the case of the non-technological innovation services. This is consistent with the notion that services are closer (and interact more) with end-users than manufacturing, and that customers have an important role in defining service products (Barcet 2010). Finally, public sources seem to have a positive impact on non-technological innovation only in the manufacturing sector.

Finally, other firm variables, such as being an exporter and foreign-owned, are not clearly linked to technological or non-technological innovation, at least beyond the impact these characteristics have on the decision to invest in innovation activities. If there is a significant additional effect, it tends to be negative (this is the case for being foreign-owned in the service sector, accessing information sources and being an exporter in the manufacturing sector). Instead, the cooperation in R&D has a positive effect only in the case of non-technological innovations in the services sector. This could hint that cooperation is more important for services because, among other things, services tend to face bigger restrictions to finance R&D than manufacturing firms (service innovations are intrinsically intangible and more subject to asymmetries information and therefore credit restrictions).

5.3. *Productivity equation*

The final stage of the CDM model, which relates the labour productivity of firms to their innovation indicators, is shown in Table 4. The measure used for productivity is the log of sales per employee, the dependent variable. As a recursive model, this stage uses the predicted probability of performing technological innovation, non-technological innovation or both at the same time using the model estimated in the previous stage. In columns 1 and 3 of panel A, we estimate the equation using the predicted innovation expenditure of stage 1 for services and manufacturing in the whole sample and the small firms subsample.

As shown in Table 4, innovation expenditures significantly and positively impact labour productivity, both in the manufacturing and services sector, and to a similar extent in each case. Furthermore, the impact is larger in small firms in both services and manufacturing.

Results show that technological and non-technological innovations are significantly associated with higher firms' productivity in the services sector (column 2 for the whole sample and 4 for small firms). Non-technological innovations have a bigger impact than technological innovations, supporting the hypothesis that innovation has a positive effect on productivity.

Table 4. Output production function (productivity equation).

	Services									
	Panel A				Panel B					
	All		Small		All			Small		
Variable\dep. var.	Log (sales/employees)									
Size	−0.0588***	−0.163***	0.130*	−0.0598	−0.0917***	−0.0412*	−0.0684***	0.129	0.141	0.151**
	(0.0211)	(0.0336)	(0.0670)	(0.0870)	(0.0266)	(0.0247)	(0.0195)	(0.0816)	(0.0895)	(0.0711)
K/L	0.0695**	0.0724**	0.0910***	0.0962***	0.0729***	0.0697**	0.0842***	0.0932***	0.0880***	0.103***
	(0.0297)	(0.0295)	(0.0263)	(0.0287)	(0.0259)	(0.0315)	(0.0286)	(0.0283)	(0.0292)	(0.0245)
Predicted log IE	0.489***		0.756***							
	(0.0756)		(0.139)							
Predicted tech innovation		1.177*		2.080*		1.536**			2.203**	
		(0.669)		(1.114)		(0.596)			(1.059)	
Predicted non-tech innovation		4.315***		4.984***			2.858***			1.691
		(0.889)		(1.641)			(0.708)			(1.157)
Predicted tech and non-tech innovation		1.358***		1.280**	1.007***			1.350***		
		(0.297)		(0.532)	(0.269)			(0.447)		
Constant	12.84***	12.95***	10.97***	12.04***	13.08***	12.71***	12.93***	12.01***	11.78***	11.96***
	(0.124)	(0.172)	(0.259)	(0.230)	(0.137)	(0.142)	(0.107)	(0.255)	(0.260)	(0.253)
Ind dumm	Yes	Yes	Yes	Yes				Yes	Yes	Yes
Observations	1093	1093	562	562	1093	1093	1093	562	562	562
R^2	0.385	0.379	0.409	0.402	0.358	0.355	0.360	0.384	0.383	0.377

	Manufacturing									
	All		Small		All			Small		
Variable\dep. Var.	Log (sales/employees)									
Size	0.188***	0.261***	0.181**	0.119	0.199***	0.144***	0.240***	0.165**	0.0375	0.310***
	(0.0300)	(0.0432)	(0.0723)	(0.102)	(0.0443)	(0.0305)	(0.0281)	(0.0815)	(0.0736)	(0.0742)
K/L	0.210***	0.208***	0.171**	0.176*	0.214***	0.212***	0.210***	0.184**	0.178*	0.177*
	(0.0514)	(0.0650)	(0.0736)	(0.102)	(0.0592)	(0.0595)	(0.0508)	(0.0907)	(0.0935)	(0.102)
Predicted log IE	0.471***		0.706***							
	(0.0965)		(0.118)							
Predicted tech innovation		1.249***		2.141***		1.448***			2.625***	
		(0.299)		(0.599)		(0.283)			(0.405)	
Predicted Non-tech innovation		−5.412***		−4.505*			−4.837***			−8.819***
		(1.292)		(2.665)			(0.974)			(1.816)
Predicted tech and non-tech innovation		−1.006***		−0.0619	0.277			1.114***		
		(0.290)		(0.360)	(0.214)			(0.424)		
Constant	11.31***	12.51***	11.11***	12.46***	12.47***	12.42***	12.64***	12.47***	12.45***	12.45***
	(0.273)	(0.176)	(0.320)	(0.262)	(0.203)	(0.143)	(0.136)	(0.273)	(0.244)	(0.264)
Observations	1209	1209	569	569	1209	1209	1209	569	569	569
R^2	0.300	0.311	0.259	0.250	0.287	0.302	0.299	0.217	0.245	0.231

Note: All regressions include industry dummies. Bootstrapped standard errors in parentheses (100 replications).
*Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level

Even though we know that non-technological innovations are more frequent in services than in manufacturing and that this could have implications in terms of the relative impact of technological versus non-technological innovations on productivity, the evidence so far is scarce. Polder et al. (2010), using data for UK firms, show that organizational innovation is the only type of innovation that drives productivity, measured as total factor productivity, and that this effect is strong in the services sector. Masso and Vahter (2012), for Estonia, find that non-technological innovation plays a positive role only in a few specifications of the productivity equation, and that in general technological innovation seems to be more important. Other previous studies, such as Mairesse and Robin (2010) and Lööf (2005) point to a more important role of product innovation than process innovation; in fact in some of their productivity regressions, the sign of the variable process innovation is negative.

Different from services, in manufacturing, only technological innovations improve productivity. Non-technological innovations, alone or in combination with technological innovations, are associated with a reduction in productivity. At least in the short run, the estimated effects are negative. In a similar regression, Crespi and Zuñiga (2012) also find a negative coefficient for the non-technological innovation variable in the Uruguayan manufacturing sector, but the coefficient is not statistically different from zero.

These results could be driven by the fact that tech innovation, non-tech innovation and doing both types of innovation are highly correlated. However, regressions which include only one of these variables at a time (panel B in Table 4) lead to very similar results.

Size is significant in all regressions: it has a positive sign for manufacturing and a negative sign for services with the exception of small services firms. This result is similar to Segarra-Blasco (2010) for Catalan firms; this author shows that firm size has a positive effect on productivity in manufacturing industries but not in services.

Finally, capital per worker is significant and positive in both sectors, but probably due to differences in the production function (services are more labour intensive), the effect is stronger in the manufacturing sector.

6. Heterogeneity across subsectors

In this section, we explore the possible heterogeneity across subsectors. The exercise of Section 5 is replicated for different sub-samples: KIBS[15] versus Non-KIBS firms in services, low versus high-tech firms[16] in manufacturing.

Table 5 shows the results for the innovation expenditure equation. When subsectors are analysed some heterogeneities but also some common factors are found. The application for patent seems to be important for all types of firms, but especially so for KIBS and High-tech firms (reflected in the larger coefficient). Probably, because KIBS and High-Tech firms are closer to the technological frontier, and because the knowledge that they generate can be codified more easily than in other subsectors patent protection could be more relevant for them. The variable public support is also relevant for all type of firms, being more important for KIBS and low-tech firms.

Size, cooperation in R&D and market sources of information are important for the decision to invest in innovation activities for all types of firms. Size is more important for manufacturing subsectors than for services subsectors, while market sources of information are more important for the services subsectors.

With respect to the amount invested in innovation activities by firms, the only two determinants that seem to be important across manufacturing subsectors are cooperation in R&D and public support. In addition, public sources of information are relevant for high-tech firms (at 10% level of confidence), and market sources of information have a positive impact in low-tech firms (again at 10% confidence). For KIBS, patent protection, cooperation in R&D and market and public sources of information are the variables that affect positively the level of innovation expenditure. Meanwhile,

Table 5. Innovation expenditure equation across subsectors.

	KIBS	Non-KIBS	High-tech	Low-tech
Variable\dep. var.	Innovation expenditure dummy (Probability of investing in innovation IE > 0)			
Exporter	0.443***	0.326**	0.179	0.0516
	(0.0257)	(0.134)	(0.112)	(0.0865)
Foreign-owned	−0.0376	0.276**	−0.152	0.164
	(0.238)	(0.130)	(0.260)	(0.148)
Patent protection	7.098***	1.348***	5.457***	1.747***
	(2.129)	(0.375)	(0.136)	(0.583)
Public support	7.699***	1.874***	1.608**	6.061***
	(1.970)	(0.481)	(0.676)	(0.135)
Cooperation in R&D	1.341***	1.194***	1.107***	2.080***
	(0.408)	(0.216)	(0.175)	(0.371)
Market information sources (Info1)	0.447**	0.557***	0.368**	0.368***
	(0.205)	(0.0802)	(0.170)	(0.135)
Scientific sources (Info2)	0.0919	−0.277**	−0.489***	−0.181*
	(0.102)	(0.113)	(0.156)	(0.105)
Public sources (info3)	−0.0122	0.0229	0.0488	0.126
	(0.0459)	(0.132)	(0.128)	(0.125)
Size	0.275***	0.255***	0.444***	0.353***
	(0.0218)	(0.0273)	(0.0605)	(0.0225)
Constant	−1.916***	−1.796***	−2.853***	−2.078***
	(0.0946)	(0.0766)	(0.371)	(0.149)
Variable\dep. var.	Log (Innovation expenditure) = Log IE			
Exporter	0.868	0.256	0.301	0.103
	(0.686)	(0.233)	(0.294)	(0.128)
Foreign-owned	0.447	0.664***	−0.0162	0.0708
	(0.514)	(0.229)	(0.132)	(0.199)
Patent protection	1.051***	0.274	−0.0486	−0.571
	(0.0853)	(0.277)	(0.141)	(0.576)
Public support	1.234	0.834	0.441***	0.708**
	(1.293)	(0.743)	(0.162)	(0.337)
Cooperation in R&D	1.269**	1.023**	0.599*	0.476**
	(0.601)	(0.494)	(0.327)	(0.204)
Market information sources (Info1)	0.781***	0.111	0.0287	0.432*
	(0.129)	(0.406)	(0.265)	(0.256)
Scientific sources (Info2)	0.424	−0.226	0.162	−0.112
	(0.279)	(0.187)	(0.279)	(0.211)
Public sources (Info3)	0.271***	0.431***	0.113*	0.0853
	(0.0863)	(0.0997)	(0.0636)	(0.154)
Constant	−1.269	0.511	2.341***	2.172***
	(1.031)	(0.457)	(0.250)	(0.468)
Number of observations	628	1240	399	1328
Censored observations	364	785	190	806
Log likelihood	−865.9	−1558	−568.8	−1690
Independence (ρ)	1.025***	0.453**	−0.00438	−0.0933
	(0.340)	(0.189)	(0.192)	(0.140)

Note: All regressions include industry dummies. Errors clustered at two digit industry level.
*Coefficient is statistically significant at the 10% level; **at the 5% level; ***at the 1% level

cooperation in R&D, public sources of information and the fact of being foreign-owned are the relevant variables for Non-KIBS services.

The only variable that is consistently significant across all services and manufacturing subsectors regressions is cooperation in R&D, being more important for service subsectors. This seems to be one of key variables that determine the level of innovation expenditures across subsectors.

Table 6 shows results for the innovation output equation across subsectors. Size seems to matter for all types of innovation (tech and non-tech) and subsectors. The amount invested in innovation activities is an important determinant of the innovation output. It seems to be more important for technological than for non-technological innovation. In fact, it seems to be not relevant for non-technological innovation in Non-KIBS services and high-tech manufacturing.

Table 6. Innovation output across subsectors.

	KIBS	Non-KIBS	KIBS	Non-KIBS	High tech	Low tech	High tech	Low tech
Variable\Dep. Var.	Tech Innovation		Non-tech innovation		Tech Innovation		Non-tech innovation	
Innovation output								
Exporter	−0.345	−0.139	−0.141	0.195**	−0.632***	−0.162	−0.742**	−0.0971
	(0.318)	(0.251)	(0.237)	(0.0963)	(0.232)	(0.136)	(0.309)	(0.0731)
Foreign-owned	−0.527	−1.236***	0.0652	0.0905	−0.356**	−0.0632	−0.111	−0.0654
	(0.382)	(0.344)	(0.0662)	(0.183)	(0.169)	(0.140)	(0.251)	(0.135)
Patent protection	0.123	1.030***	−0.506	0.916**	1.662***	2.374***	0.961***	0.986***
	(0.282)	(0.320)	(0.432)	(0.367)	(0.112)	(0.436)	(0.111)	(0.218)
Cooperation in R&D	0.0572	−0.469	0.114	0.363*	−0.162	0.215	−0.507	0.410**
	(0.0422)	(0.630)	(0.442)	(0.220)	(0.429)	(0.270)	(0.597)	(0.172)
Market information sources (Info1)	−0.287***	0.435***	0.263	0.594***	0.0346	−0.462**	0.830***	−0.183*
	(0.0101)	(0.0797)	(0.443)	(0.115)	(0.204)	(0.206)	(0.170)	(0.104)
Scientific sources (Info2)	−0.386*	0.0712	−0.176***	−0.0309	−0.927***	0.0211	−0.523**	0.0833
	(0.218)	(0.153)	(0.0162)	(0.0505)	(0.186)	(0.120)	(0.247)	(0.0573)
Public sources (Info3)	−0.155**	−0.741**	−0.195	−0.0650	−0.166	0.0255	0.172	0.254*
	(0.0733)	(0.295)	(0.129)	(0.155)	(0.244)	(0.105)	(0.256)	(0.149)
Size	0.145***	0.225***	0.215***	0.240***	0.365***	0.340***	0.360***	0.288***
	(0.00309)	(0.0158)	(0.0236)	(0.0281)	(0.112)	(0.0306)	(0.0720)	(0.0329)
Predicted log IE	0.888***	1.907***	0.587*	0.366	2.993***	2.273***	1.367	0.534**
	(0.259)	(0.576)	(0.337)	(0.240)	(0.928)	(0.392)	(0.840)	(0.262)
Constant	−0.549***	−2.941***	−1.511***	−2.650***	−9.360***	−7.399***	−6.481***	−3.461***
	(0.209)	(0.359)	(0.445)	(0.120)	(2.427)	(0.871)	(2.249)	(0.635)
Number of observations	628	1240			399	1328		
Log likelihood	−637.5	−1165			−394.2	−1179		
Independence (rho)	0.618***	0.533***			0.543***	0.548***		
	(0.0304)	(0.0344)			(0.0602)	(0.0492)		

Note: All regressions include industry dummies. Errors clustered at two digit industry level.
*Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level

Patent protection tends to have, in general, a positive impact across types of innovation and subsectors, and again it seems to be more important for the production of technological innovations. The evidence indicates that patents are not an important determinant of the innovation output produced in KIBS. Cooperation in R&D seems to be an important determinant only for non-technological innovation in the Non-KIBS services and low-tech industries.

Finally, Table 7 shows the results for the determinants of productivity. Results show that non-tech innovation has a bigger impact on the productivity of services subsectors than tech innovation. Tech innovation is more important for productivity in Non-KIBS service firms than in KIBS. The reverse happens in the case of non-tech innovations. When innovation expenditure is used as a proxy for innovation a positive impact on productivity is found in both services subsectors, but it seems to have a more important role in the case of Non-KIBS services.

In the case of manufacturing, technological innovation is what matters for productivity in the low-tech firms. Non-tech innovation tends to have a negative effect on productivity on both manufacturing subsectors. The negative effect is larger (and significant) in the case of high-tech firms. When (the predicted value of) innovation expenditure is used as proxy for innovation, we find that innovation is important for productivity for all types of manufacturing firms, but it is more important for low-tech manufacturing.

7. Conclusions

In this paper, the links between the investment in innovation activities, innovation outputs (technological and non-technological) and productivity in services and manufacturing is explored using CIS-like data for Uruguay. This is one of the first attempts to study these links for the services sector vis-à-vis the manufacturing sector with a focus on the interaction of technological and non-technological innovation.

Results indicate that size is important for every step in the CDM model, from the decision to innovate to the impact of innovation on productivity. The new evidence shown here is that size is in

Table 7. Innovation and productivity.

	KIBS		Non-KIBS	
Variable\dep. var.	Log (sales/employee)			
Output production function (productivity equation)				
Size	−0.192***	−0.393***	−0.0141	−0.151***
	(0.0429)	(0.0658)	(0.0249)	(0.0441)
K/L	0.630	0.678**	0.0642**	0.0663**
	(0.385)	(0.344)	(0.0284)	(0.0314)
Predicted log IE	0.237***		0.526***	
	(0.0492)		(0.0870)	
Predicted tech innovation		0.508		1.880***
		(0.667)		(0.677)
Predicted non-tech innovation		6.273***		3.605***
		(1.344)		(1.162)
Predicted tech and non-tech innovation		1.427***		1.184***
		(0.485)		(0.382)
Constant	13.89***	14.03***	12.53***	12.75***
	(0.198)	(0.335)	(0.134)	(0.177)
Observations	343	343	750	750
R^2	0.301	0.333	0.342	0.340
	High tech		Low tech	
Size	0.163**	0.305***	0.195***	0.184***
	(0.0659)	(0.0887)	(0.0398)	(0.0457)
K/L	0.230***	0.224***	0.202**	0.202**
	(0.0574)	(0.0415)	(0.0984)	(0.0837)
Predicted log IE	0.357**		0.474***	
	(0.145)		(0.112)	
Predicted tech innovation		0.438		0.822**
		(0.458)		(0.360)
Predicted non-tech innovation		−4.984***		−2.962
		(1.307)		(1.893)
Predicted tech and non-tech innovation		−1.102***		0.0656
		(0.371)		(0.313)
Constant	12.20***	12.94***	11.28***	12.57***
	(0.460)	(0.305)	(0.313)	(0.156)
Observations	281	281	928	928
R^2	0.370	0.374	0.239	0.250

Note: All regressions include industry dummies. Bootstrapped standard errors in parentheses (100 replications).
*Coefficient is statistically significant at the 10% level; ** at the 5% level; *** at the 1% level

general more important in manufacturing than in services. One possible interpretation of this evidence is that innovation in services requires less formal processes of innovation and therefore demands smaller fixed costs than manufacturing. Hence, policies that help us to reduce the fixed costs of investment in innovation could be key in order to promote innovation in both manufacturing and service sectors, but most importantly in manufacturing where technological innovations are more frequently developed.

Public financial support is positively associated with the decision to invest in innovation, and also with the level of innovation investment in the case of manufacturing firms. Therefore, the access to external financial resources appears to be important for innovation. Furthermore, those firms that cooperate with others in R&D tend to have a greater probability of investing in innovation and also invest more in innovation. It is interesting to note that the biggest impacts are found for small firms. Patent protection is also relevant for the decision to invest, while it has no further impact on the level of innovation investment. Patent protection is more important for innovation in manufacturing than in services and for technological innovations. This is an expected result: services firms tend to rely less on patents and tend to generate innovations that are less patentable. Knowledge in services is less tangible and codified than in manufacturing (and this is especially true for non-technological knowledge). Therefore, patents are less relevant as an intellectual property protection device and less relevant in the knowledge (innovation) production function in services, in particular for non-technological knowledge. Overall, the results imply, if we interpret this correlation as causality, that policies to create R&D collaboration networks can have an important impact on the decision to invest in innovation activities, particularly for firms of relatively small size. Public financial support for innovation activities could also be important. The promotion of intellectual property rights, and patents in particular, could also have a positive impact on the decision of carrying out innovation activities. Finally, since market sources of information (clients, suppliers, etc.) are important, policies aimed at improving communication between firms and these different agents can have an impact on innovation activities. Other characteristics of firms, such as being an exporter or foreign-owned, or the use of other sources of information (public or scientific) are not clearly linked (either by sign or significance) to the decision of investing in innovation activities.

Technological and non-technological innovations are linked to each other in both the services and in the manufacturing sectors. Furthermore, the determinants of both innovations are similar to each other and at the sectoral level. Apart from size, the most relevant variable in the technological and non-technological innovation output functions is the level of investment in innovation activities. The level of investment is more important for technological innovations, consistent with the fact that non-technological innovations arise from less-formalized and more ad-hoc activities. This implies that the level of investment is more important for manufacturing innovations than for services innovations since manufacturing firms innovate more through technological innovations. Patent protection is also an important factor associated with innovation, but, as expected, is more relevant for technological innovations and manufacturing.

For productivity in services, innovations, both technological and non-technological, are very important. But non-technological innovations have a greater impact on services' productivity, and particularly on Non-KIBS services vis-à-vis KIBS. In the case of manufacturing, only technological innovations are found to increase productivity, especially in low-tech sectors. This heterogeneity could have important implications for policy. Incentives to innovate must be directed where they have greater impact on productivity; this implies a greater focus on non-technological innovations in the case of services firms and on technological innovations in the case of manufacturing firms.

Technological innovations are more important for the productivity of small firms. Probably because they are far away from the technological frontier, improvements here generate bigger gains in productivity than in other firms. From the policy point of view, this could imply that facilitating the ability of the financial or legal access of small firms to new technology could be a way of generating a reduction in the productivity gap of this type of firm.

Acknowledgment

We thank the comments and suggestions by Gustavo Crespi and participants of the workshops of the research project Innovation and Productivity in Services of the IDB, IDRC and CINVE that took place in Lima, Peru and Panama City, Panama, and Globelics 2013. The views expressed here are those of authors and do not necessarily reflect those of the OECD.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Innovation surveys are now being increasingly used in studies to explore innovation in service sectors from different perspectives; barriers to innovation, types of innovation or innovation activities in specific service sectors (Evangelista 2000, 2006; Howells and Tether 2004; Arundel et al. 2007; Gotsch et al. 2011). However, most of the available literature about innovation and productivity is concerned with technological innovations and their impact on productivity in the manufacturing sector.
2. This paper is an output of a research project of the Inter-American Development Bank on innovation and productivity in services that took place in Brazil, Chile, Colombia and Uruguay.
3. Community Innovation Survey.

4. These countries are: Australia, Austria, Denmark, Finland, France, Germany, Netherlands, New Zealand, Norway and United Kingdom.
5. The data are collected in parallel with the economic activity survey (EAS) (same sample and statistical framework). All the firms with more than 49 workers are mandatorily included. Units with 20–49 employees and with fewer than 19 workers are selected using simple random sampling within each economic sector at the ISIC 2-digit level up to 2005. Since then, random strata are defined for units with fewer than 50 workers within each economic sector at the ISIC 4-digit level.
6. The matching with the EAS was not without loss. The 2004–2006 SIS was performed with the same sampling frame of the EAS 2005. This implied that a significant number of firms that were surveyed in the 2004–2006 SIS, did not participate in the 2004 EAS. A similar problem arises when matching the 2007–2009 SIS (which is a subsample of the 2009 EAS) and the 2007 EAS. Both facts explain the loss of observations when matching the surveys. Firms with missing information were also excluded, as were the 1st and 99th percentile of productivity and the 99th percentile of innovation expenditures per employee.
7. Our data do not have a panel structure; therefore we are using pooled cross-section data for the estimations. Most of the papers in the microeconometric innovation-productivity literature, and particularly those papers that use the CDM model, have the same data constraints than us.
8. The manufacturing innovation surveys are representative of the entire manufacturing sector, that is, Chapter D, divisions 15–37 of the International Standard Industrial Classification Revision 3.
9. A simple two-sample *t* test with equal variances rejects the null hypothesis of the means of the share of firms being equal in manufacturing versus services at 1% for both technological ($t = -2.86$) and non-technological innovation ($t = 4.62$) against the alternative hypothesis of being positive and negative, respectively.
10. The CDM model is the workhorse model in the innovation and productivity microeconometric literature; see Hall (2011) for a review of the literature.
11. The selection bias arises because in each time period only of handful of firms report positive investment in innovation activities. Deleting firms with zero activity will bias the sample. It is important to note that the elimination of this bias becomes even more important when applying the model to the services sector, for services are characterized by an informal and ad-hoc nature of their innovation activities.
12. Innovation indicators from innovation surveys are noisy (partly due to the fact that they are subjective measures) and hence contain measurement errors. Hence, factors that are not observed and that affect the probability of innovation may lead companies to invest more in innovation activities. Furthermore, other unobservable factors which explain productivity may also affect the choice of inputs implying correlation between the error in the productivity equation and explanatory variables.
13. Of course this does not need to be the case, but we are following here the reasoning of Crépon, Duget and Mairesse (1998, 4): 'without good a priori reason to do otherwise we actually included the same set of variables in both equations'. In fact most of the papers that use the CDM model do the same.
14. A similar approach is used for instance by Hall, Lotti, and Mairesse (2014) and Masso and Vahter (2012).
15. KIBS are defined using ISIC 3.1 codes: 72, 73 and 74 (Except 7492, 7493 and 7499).
16. High tech firms in the manufacturing sector are defined using the ISIC 3.1 codes: 24, 29, 30, 31, 32, 33, 34 and 35 (except 351).

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Appendix

Table A1. Definition of variables.

Variable	Source	Description
Tech innovation	IS	Dummy = 1 if firm introduced product or process innovation in the period of the survey
Non-tech Innovation	IS	Dummy = 1 if firm introduced organizational or marketing innovation in the period of the survey
Productivity	IS	Log(sales per employee). End of year of survey.
Innovation expenditure (IE)	IS	R&D expenditures and other innovation expenditures such as design, installation of machinery, industrial engineering and embodied and disembodied technology (capital and machinery, patents, patent and trademark licensing, disclosures of know-how and computer and other technological services), and design, marketing and training, per employee. Year-end survey.
Size	IS	Log number of employees. Year-end survey
Foreign-owned	IS	Dummy = 1 if foreign capital greater than 10%. Year-end survey
Patent protection	IS	Dummy = 1 if firm applied for patent in the survey period
Exporter	IS	Dummy = 1 if firms exports. Year-end survey
Public support	IS	Dummy = 1 if firm obtained financial support from government in the period of the survey
Cooperation in R&D	IS	Dummy = 1 if firm was linked to some institution for design or R&D in the period of the survey
Market information sources (Info1)	IS	Dummy = 1 if importance of market sources (suppliers, clients, competitors, consulting firms and experts) was very important or important in the period of the survey
Scientific sources (Info2)	IS	Dummy = 1 if importance of scientific sources (universities, public research centre and technological institutions) was very important or important in the period of the survey
Public sources (info3)	IS	Dummy = 1 if importance of public sources (journals, patents, magazines, expositions, associations, databases and internet) was very important or important in the period of the survey
K/L	EAS	Total fixed assets over employees. Year-beginning survey

Table A2. Descriptive statistics of variables included in regressions.

	Mean	Std. dev.	Min	Max
Manufacturing				
Tech innovation	0.4	0.5	0	1
Non-tech Innovation	0.2	0.4	0	1
Productivity	1649	2491	56	25,713
Innovation expenditure (IE)	23	62	0	633
Size	3.6	1.2	0	7.7
Exporter	0.4	0.5	0	1
Foreign-owned	0.1	0.3	0	1
Patent protection	0.0	0.1	0	1
Cooperation in R&D	0.1	0.2	0	1
Market information sources	0.9	0.4	0	1
Scientific sources	0.3	0.4	0	1
Public sources	0.7	0.4	0	1
Public support	0.0	0.2	0	1
K/L	0.6	1.6	0	21
Services				
Tech innovation	0.3	0.5	0	1
Non-tech Innovation	0.2	0.4	0	1
Productivity	1119	2192	18	31,936
Innovation expenditure (IE)	15	52	0	536
Size	3.7	1.4	0	9
Exporter	0.1	0.3	0	1
Foreign-owned	0.1	0.3	0	1
Patent	0.0	0.1	0	1
Cooperation in R&D	0.0	0.2	0	1
Market information sources	0.9	0.3	0	1
Scientific sources	0.3	0.5	0	1
Public sources	0.7	0.5	0	1
Public support	0.0	0.1	0	1
K/L	0.8	3.2	0	62