Innovation decision and firm productivity: An empirical analysis for the services sector[Ψ]

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Abstract

The primary aim of the paper is to explore the relationship between productivity and innovation based on a large firm-level data set for service and manufacturing sector in the period 2010-2011. The novelty of the approach lies in make an analysis from innovation surveys of the Colombian Statistical comparing Knowledge intensity business sector (KIBS) and manufacturing. Innovation activities of firms are modelled as a four stage model (CDM) which allows studying several interrelated questions while controlling for public support for innovations. In the first two stages determinants of being supported by the government and the decision to innovate and consequent innovation investment are separated. In the third stage innovation input (innovation investment) is linked to innovation output, and finally, in the fourth stage it is determined how the productivity of firm is related to its innovation activities. In this final stage we explore the heterogeneous effects across the productivity distribution function using quantile regressions. Our analysis proved that innovation input significantly increases innovation output, but it does not true for services companies. This result may throw a shadow on the efficiency of supported firms and have some implications for competition policy.

Keywords: innovation, CDM-model, productivity, public support

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1. Introduction

In the past decades, the emerging economies have seen significant growth in service activities, generating about 60% of the value added per employee in Latin America, Southeast Asia and Eastern Europe. In addition, knowledge-intensive sectors have been growing in real terms at rates above the normal growth of the economy. Especially in Latin America, such sectors have an annual compound growth rate close to 13% (IMF, 2014). Behind these facts, many issues that have attracted the attention of several scholars and policy makers, merge. For example, what role does innovation play in these economies?; which factors determine the level of innovation?; and what is the relationship between productivity and innovation for the services sector?

However, the studies that have attempted to resolve such questions have focused on the manufacturing sector and developed economies. In turn, the availability of surveys has enabled the development of this type of research. Regarding the services sector, some studies have tried to explore the role of investment in innovation, its determinants and effects on productivity, especially in OECD countries, e.g. Crepon et al. (1998), Kremp and Mairesse, (2004), Mairesse and Mohnen, (2005), Duguet, (2006), Mairesse and Robin, (2010). However, there is little empirical evidence for emerging and developing countries. For example, for Latin America, Tello (2015), Crespi and Zuniga (2012), Raffo et al. (2008), Benavente (2006); Chudnovsky et al. (2006) are works that examine the determinants of innovation and its effect on productivity level using data at firm level. However, these papers perform an analysis to the manufacturing sector.

Therefore, one of the purposes of this paper is to fill the gap on the analysis of the relationship between innovation and productivity in services sector, analyzing the effect of different innovation activities (product, processes, etc.) on the firm's economic performance. That is why we are trying to estimate a model that evaluates the innovation decisions, output innovation and their impact on productivity. For this reason, this paper attempts to address four questions: i) First, we will find the determinants of investment in innovation. ii) We will see how services companies innovate and what their effects on productivity are? iii) Additionally, we will analyze the effects into the service sector: Is the effect different for companies in the KIBS vs industry? iv) Finally, regarding with the role of public support, what determines the probability of obtaining public support? How has it an impact on innovation?

The strategy that we have adopted in this paper, takes the model developed by Crépon-Duguet-Miresse (1998) called (CDM). This model is defined as structural model where the decision to invest in innovation and the output innovations are assessed, and then, the model assesses how these factors have an effect on the firm productivity. The conceptual framework of this model takes into account innovation as a process, which is carried out by companies with a specific set of inputs (R&D activities, acquisition of technology, among others) and interactions with other firms and institutions. This innovative process should produce certain outputs which take different forms. The most visible are related to new or modified products (for the firm or the market). Finally, the innovations outputs are not the end of the process, those firms which have launched new or improved products or processes expect to have a better performance in relation to non-innovators.

For this purpose, data on manufacturing and services companies for Colombian economy is taken, this is due to the availability of a reliable source of information and the importance of these sectors in this economy[1]. For that, we implemented a four stages strategy. i) the determinants of being supported by the government, ii) we have estimated the decision to innovate and the investment determinants using standard procedures iii) the innovation or knowledge production function, where the innovation output refer to product, process, marketing and organizational innovation iv) we study whether the output innovations that deal with products and processes, but also organizational and marketing improvements cause a subsequent return on productivity.

The main contribution of this paper is to present evidence of the relationship between public support, innovation investment, output innovation and productivity in the Colombian service sector. In this context, the aim of the paper is to contribute to the limited literature related to technological effort in the service sector, using a modified version of the CDM model. The adjusted model allows to estimate the role of public support, and controlling for heterogeneity on the firm's performance. In turn, one of the contributions is to evaluate the effect of public support on current innovation decision. In this case, it aims to answer questions such as: How public support affect the firm's innovative behavior? What is the relationship between public support and innovation? What impact does innovation have on firm's productivity?

So far, the service sector in Colombia has not been studied from the point of view of technological effort. To do this, we have decomposed this sector between traditional and knowledge intensive business sector (called KIBS[2]), we also want to establish a line of comparison between these sub-sectors and the manufacturing sector. For that, we use the Technological and Innovation survey available for Manufacturing and Service companies in Colombia.

This paper is organized as follows: In the next section there is a review of the previous empirical work, in the third part we describe the data used, the sources of information and show some stylized facts. In section 4, the empirical strategy adopted is discussed, and then in section 5 we present the results and in section 6 the conclusions and recommendations are shown.

2. Related literature

In this section we present the main studies that have attempted to analyze the two main blocks of the CDM model. In the first part, we present the studies that have analyzed the determinants of the decision to innovate which have been applied to the service sector. In the second part we present the studies that have tried to find the relationship between the production of innovations and firm's economic performance, it is the second block of CDM model.

[1] About 70% of GDP in Colombia is represented by the production of services, and 15% by manufacturing (DANE, 2014)

[2] KIBS= corresponds to the acronym "*Knowledge Intensive Business Sector*". For empirical effects Miozzo and Grimshaw (2006) provide a definition of these industries, which are based on: Computer Science and related activities, R & D and other industries. Citing this definition: "these services involve the intensive use of advance technologies, specialized skills and professional knowledge" (Miozzo and Grimshaw 2006, p.1). We use the acronym KIBS hereafter.

2.1 Additional Possible Determinants of Firm Innovation

The Crepon, Duguet and Mairesse (CDM) model was developed by Crepon, Duguet and Mairesse (1998) and is based on the seminal studies by Griliches (1979) and Griliches and Pakes (1980, 1984). The model has two main analytical parts: i) an analysis of the relation between the decision to invest in innovation and the cost or (intensity) of innovation and ii) an analysis of the innovation production function and its effect on productivity. These two parts are interrelated because innovation intensity (from the first part) is a determinant of innovation production, which affects the productivity or economic performance of firms.

Figure 1 shows a diagram of the model's general structure. The first step is making the decision to designate financial and human resources for innovation activities. Next, the quantity of designated resources provides a measurement of the intensity of these activities at the firm level. In the third step, there is (or should be) innovation production (of a product, process or both) related to intensity[3] and other characteristics of the innovation process (e.g., interactions with other agents of the national science and technology system, strategies, cooperation). Finally, the firm's performance must be related to the produced innovation.

The CDM model has been applied to different countries, both developed and developing. In the latter category, Argentina (Chudnovski, Lopez and Pupato 2006), Chile (Benavente 2006), China (Jefferson, Huamao, Xiaojing and Xiaoyun 2006), Peru (Tello 2015) and Tanzania (Goedhuys, Janz and Monhen 2008) are notable. However, all of these studies have been performed on the manufacturing industry.

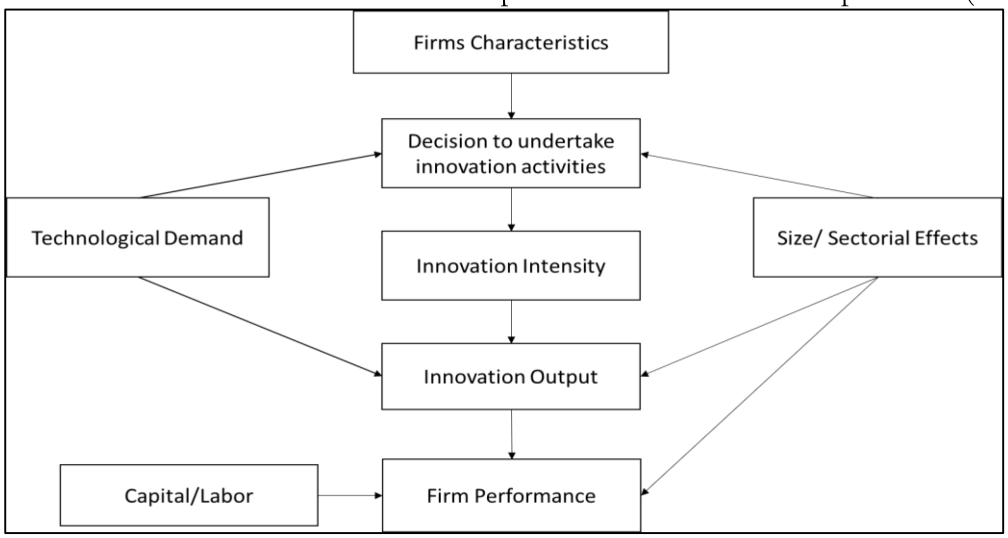
In developed countries, a number of studies were performed on the service sector and attempted to analyse the determinants of the decision to innovate. Several of the most recent such studies are found in Table 1. Of the most common determinants, a firm's tendency to innovate is related to the size of the firm. However, the results for this variable do not enable a straightforward conclusion. Although the effect of size on the decision to innovate is positive for the manufacturing sector, it seems that in the service sector (specifically in knowledge-intensive business services-KIBS)) this variable does not explain the decision to innovate. For example, using a sample from Germany, Koch and Strotmann (2008) estimated a multinomial logit model that analysed the determinants of incremental and radical innovations. They found that firm size did not affect the innovation decisions of firms. Musolesi and Huiban (2010) reached the same conclusion by estimating the effect of firm size using a reduced version of the CDM model for a cross section of service-sector firms from Germany and France.

Another variable that influences innovation decisions and the innovation effort of firms in the service sector concerns financial obstacles, access to information and potential demand risks. (The latter are a product of market uncertainty or the potential participation of a market firm.) Several studies have attempted to evaluate the impact of these factors on the innovation decisions of firms. For example, Arvanitis (2008) analyzed the effect of the access to funding on the innovation decision using a cross section of Swiss service-sector firms. The author concluded that there was a

3 Undertaken innovation activities is not the same as being innovator and for being an innovator is not always needed to have innovation expenditures.

slightly positive effect, which reflected the presence of liquidity restrictions. However, most studies have not evaluated how the innovation decision is affected by restrictions of a financial nature. This factor is important to analyze because a major financial restriction could prevent a firm from taking on innovation projects. However, a major financial restriction could also increase the probability of accessing benefits or public support to carry out these innovation projects.

Figure 1: Theoretical Model: Innovation and firm performance: Based on Crepon et al. (1998)



This last aspect is significant to the extent that factors such as economic informality and the presence of a determined number of small firms that face obstacles in accessing financial mechanisms (whether public or private) become determinants of the innovation decision. For example, Musolesi and Huiban (2010), in addition to studying the compound model and its effect on productivity, identified the determinants and effects of innovation on KIBS firms while comparing these effects with the manufacturing sector using a cross section from France. Within the determinant variables of the decision to invest in innovation, they found that variables such as firm size and public support were not significant at the time of explaining the product and process innovations.

In addition, variables such as the type of property (i.e., foreign) and the exposure to international markets (measured by the level of exports, for example) have been evaluated in studies by Peters et al (2014) and Vahter and Masso (2012). These studies found that property type and the level of exports have positive effects on the decision to innovate in the industrial and service sectors. Extended versions of the CDM model were used.

Regarding Latin America, a study by Crespi and Zuniga (2010) used a version of the CDM model for a sample of firms in six economies. It was found that a number of the determinants of the tendency of industrial firms to innovate concerned cooperation, exports and foreign property. These three variables had a positive and significant effect on the probability of initiating innovations, but not in all of the sampled countries. For example, for Colombia, these variables were not significant. In addition, it was found that the sources of information had a minor effect on the innovation effort of the firms.

Table 1: Some recent works on the determinant of Innovation Decision

Author	Sector	Country	Industry Fixed	Size	Foreign group	Exports	Formal Protection	Barriers	Other controls
Peters et al (2014)	S, M	Germany, Ireland, United Kingdom	Yes	+	+	+	No	No	Industry fixed effects Demand Pull
Vahter and Masso (2012)	S KIBS M	Estonia	Yes	+	+	+	Ns	Ns	Public funding Domestic group
Musolesi and Huiban (2010)	S KIBS	France	Yes	Ns	No	+	No	No	Demand pull Other external sources Corporate source of knowledge
Stelios and Aristotelis (2009)	KIBS	Greece	Yes	+	No	+	No	Ns	Group member
Arvanitis (2008)	S	Switzerland	No	+	No	No	+	-	Knowledge source of information Expected change in demand
Mairesse and Robin (2008)	M S	France	Yes	No	No	No	+	No	Demand pull/ technology push Source of information
Koch and Strotmann (2008)	KIBS	Germany	Yes	Yes	No	+	No	No	Skills Share of Turnover with Clients R&D expenditures Firm age

Note: M: manufacturing; *S*: services; *KIBS*: Knowledge intensive Business Sector; *Ns*: no significant; No: no applied.

In sum, regarding the determination of the innovation probability of firms, the literature generally does not provide an analysis of the determinants of the decision to innovate in the service sector of developing economies. Studies have been performed on more developed economies, and the following variables have been examined as determinants of the tendency to innovate: firm size, foreign property, export experience of the firms and sources of knowledge. However, the literature has not thoroughly analyzed the effects of self-selection or the effect of obstacles on innovation and access to public subsidies.

Thus, we wish to verify is if the implementation of innovation activities has a positive effect on innovation production such that firms that develop innovation activities have a high probability of achieving innovations. Therefore firms that introduce innovations during period t have developed science, technology and innovation projects. In addition, we would like to determine whether the firms that have exhibited an innovation effort in the past maintain a persistent path toward their goal in the following term.

Finally, regarding public support for innovation, although an ample spectrum of channels exists through which public policy could affect the innovation dynamic of firms and their productive design, two of the most important tools concern subsidies or direct support and tax incentives. Public financing for R&D can affect productivity through its impact on the cost of research and through this research on product and process innovations.

Therefore, we expect that firms that accept public benefits have a higher probability of innovating. To demonstrate the validity of this statement, we must calculate the effect of public financing on the decision to innovate and the production of innovations. The former suggests determining whether public support of innovation activities is efficient because the firms that use it can exhibit better performance on the productive level and in their innovative activities compared with firms that have not received such support. A number of studies have analyzed the effect of public subsidies on financing investigation and development activities, for example, Takalo et al (2013), Foreman-Peck (2013) and Busom et al (2014).

2.2 The effect of innovation on productivity

Regarding the second part of the CDM model, i.e., the analysis of the effects of innovation on the economic design of firms, several studies have attempted to capture this effect using distinct classes of innovation and productivity. Empirical applications that have used the CDM model tend to find differing results. A wide range of studies using European data have found that productivity positively correlates with innovation production. Among these studies, Mohnen et al (2006) and OECD (2009) are notable. These studies also found that firms that invested more intensely in R&D had a higher probability of developing innovations (either product or process innovations or patents) once the endogeneity was corrected for and controlled by specific firm characteristics, such as size, affiliation with a business group or the adoption of another type of innovation strategy (e.g., the externalization of knowledge and cooperation in R&D activities).

Table 2 summarizes the previously mentioned studies according to the sectors and countries that were studied and the signs of the effects estimated according to the adopted innovation class. The most recent studies have used labour productivity as a design indicator, measured based on the proportion of employee sales or the added value of the employee. In contrast, studies that use the function of direct or indirect production take advantage of the availability of surveys that enable follow-up over time (Data Panel)[4].

In addition, it was found that the innovation classes used by various papers were diverse. Whereas certain studies used discrete variables that revealed innovation output, others used continuous indicators. The most recent studies tend to use discrete indicators that are related to the introduction of product innovations, processes at the technological level and non-technological innovations concerned with improved organizations and marketing.

After evaluating the effects of dummy indicators on productivity, Peters et al (2014) used a larger CDM model for Germany, Ireland and the United Kingdom. Cross-section data from 2008 were used for the service and industrial sectors. In the equation that measured the effects of innovation on productivity, six indicators were evaluated, including product innovation, processes, new products for the market and for the firm and dummy indicators for organizational innovation and marketing. For Germany and the United Kingdom, all of these indicators had a positive effect on productivity. However, for Ireland, only the variable for products introduced by the firm that were new to the firm was significant. It was observed that innovation in service firms was related to high productivity. However, the determinants of innovation for services and industry were observed to produce highly similar results.

In contrast, Musolesi and Huiban (2010) analyzed the effects of a limited degree of innovation (of products, processes, technological innovation or non-technological innovation) using an innovation function and a production function augmented with a variable for dummy endogenous innovation for a cross section of the French service sector. The originality of their analysis is that they estimated the effects for KIBS firms. The study found that innovation had a strong and positive effect on productivity (measured by the added value of the employee). However, this outcome was not the case for organizational innovations. In addition, the study found that in KIBS, as in the manufacturing sector, the primary determinant of the decision to innovate was the formal knowledge that results from R&D activities or the acquisition of equipment, licenses or software.

The evidence for the ability of firms to transform their innovative efforts or their R&D efforts into innovations is mixed, for example, Crespi and Zuniga (2010), which analyzed the relationships between productivity and innovation for six Latin American economies. The study concluded that all of the countries in which firms invested in innovation had better productivity and a higher capacity for introducing new products into the market. However, other studies present different results. Raffo et al (2008) found a significant impact of product innovations on the productivity of Brazil and Mexico but not on that of Argentina.

[4] For example Van and Klomp (2006) estimate the effect of innovation on productivity using total factor productivity (TFP) as a performance indicator.

In a recent study, Tello (2015) (based on a CDM model applied to Peru) demonstrated that the largest firms were those that had a higher probability of achieving technological and non-technological innovations. In addition, the intensity of innovation spending and public financing were factors that indicated a probability of achieving innovations. Moreover, innovation intensity increased the total productivity of factors in low-technology firms but not in high-tech industries. In contrast, Chudonovky et al (2006) and Benavente (2006) did not find a significant effect of innovation on the productivity of firms (measured by employee sales). Crespi and Zuniga (2010) argued that this finding reflected that firms in developing countries were distant from the technological frontier and that their incentives to invest in innovation were weak.

Table 2: Some recent works on the effect of innovation

Author	Kind of Productivity	Sector	Country	Kind of innovation	Estimated Effect
Peters et al. (2014)	Labor productivity	S M	Germany, Ireland, UK	Product Market Novelties Enterprise Novelties Process Organizational Marketing	+, ns, + +, ns, + +, +, + +, ns, + +, ns, + +, ns, +
Vahter and Masso (2012)	Labor productivity	S, KIBS M	Estonia	Product Process Organizational	+, +,+ +, ns, + +, ns, +
Crespi and Zuniga (2010)	Labor productivity	M	Argentina Chile Colombia Costa Rica Panama Uruguay	Technological Innovation Non Technological Innovation	+ , + +, ns +, + ns, ns +, ns +, ns
Musolesi and Huiban (2010)	Value Added per employee	S KIBS	France	Either innovation Product Process Technological innovation Non-tech innovation	+ + ns ns
Griffith et al. (2006)	Labor productivity	M	France, Germany, Spain, UK	Product, Process	+, + ns, ns ns, + ns, +
Ornaghi (2006)	Production Function	M	Spain	R&D (process, product)	+
Jefferson et al. (2006)	Production Function	M	China	Share of innovative sales	+
Van and Klomp (2006)	Prod. Function (level) Prod. Function (log differences)	M	Netherlands	Share of innovative Sales	ns

Note: M: manufacturing; *S*: services; *ns*: no significant; *KIBS*: Knowledge intensive Business Sector. *ns*: no significant

There are no studies on Latin America that evaluate the effect of product and process (i.e., technological) innovations or measure non-technological innovations in the productivity or design of firms for the service sector. Therefore, we can expect that the innovative efforts of service firms in Colombia will have a positive effect on innovation production but no effect on firm productivity. To verify this, we wish to confirm whether product, process, marketing and organizational innovations have an effect on employee sales in the traditional service sector and KIBS.

3. Data and Descriptive Analysis

In this paper we use two firm-level datasets gathered by the Colombian National Statistics Department (DANE in Spanish): First, the Survey of Innovation and Technological Development in Services EDITS-III (2010-2011) and second, the Survey of Innovation and Technological Development in Manufacturing for the period 2009-2010. They use the International Standard Industrial Classification of all economic, activities ISIC Revision. 3 classification to one digit. The target population is private, individuals and legal enterprises with economic activity[5].

First, the development and technological innovation survey for the services sector EDITS (2010-2011), and second, the development and technological innovation survey for manufacturing EDIT (2009-2010). Both surveys are conducted by the National Statistics Department (DANE in Spanish). They use the International Standard Industrial Classification of All Economic Activities (ISIC Rev. 3 classification to one digit). The target population is private, individuals and legal enterprises with their economic activity.

The structure of the surveys is such that cross-section information for the service sector and manufacturing can be used. The statistical operation that is developed in EDIT is of a census type because it accommodates all of the industrial firms that satisfy the inclusion parameters. The sample consists of establishments of 10 or more employees or with an annual production greater than USD $68,700 according to the directory of firms included in the Annual Manufacturing Survey (ASM). For those surveys applied to the service sector (EDITS), there were different inclusion parameters: sales or labour (Table A1: see appendix). In both surveys (industry and services), the indicators are designed as ratios or relations, which facilitates tracking the percentage variations in national sales that correspond to innovations achieved by the firm; total amounts invested in scientific, technological and innovation activities; the level of education reached by employed personnel; and other variables.

The variables used in this study are defined in Table A2. To enable comparisons between the different sectors and sizes, Table 3 suggests the range of innovation activities for the service sector in general, the traditional service sector, the manufacturing industry and KIBS firms.

[5] We are grateful to Dane for access to the survey Development and Technological innovation in services and industry (EDIT in Spanish and hereafter) under strict confidentiality requirements, and for help in constructing the final working sample. This work contains statistical data which is Crown Copyright; it has been made available by the National Statistics Department (DANE) of Colombia and has been used by permission. The DANE does not bear any responsibility for the analysis or interpretation of the data reported here

First, it is noted that the frequency of product innovation versus process innovation is similar throughout all of the sectors (columns 3 and 4). These small differences can also be observed in the total percentage of innovative firms (column 5). Regarding the tendency to innovate in a technological manner, nearly 26% of firms in the traditional sector and KIBS report having achieved a process or product innovation. This tendency is 30% for industrial firms. In addition, it is noted that for all types of innovation (technological and non-technological) the tendency increases according to the size of the firms. Thus, in traditional firms, 11.6% of small firms (25-50 employees) report having achieved product innovations, compared with 8.35% for KIBS firms. For medium-sized firms (50-150), this tendency is 19% (traditional service firms) and 22% (KIBS firms). The tendency for large firms (with a workforce greater than 150 employees) is 22% and 30% for traditional service sector and KIBS firms, respectively.

Finally, in columns 8 and 9 of Table 3, the tendencies to innovate in a technological (product and/or processes) or non-technological (marketing and/or organizational) manner are shown. First, one can observe that for all of the sectors, the tendency for technological and non-technological innovation is similar: 35%, 32% and 37% for the traditional service sector, KIBS and manufacturing, respectively. However, these tendencies differ according to firm size. For example, in the manufacturing sector, the coefficient is 23% for small firms, 40% for medium firms and 56% for large firms.

The utmost result is that, contrary to what one could have expected, the percentage of service firms that introduced non-technological innovation was fewer than the percentage of firms that introduced technological innovation regardless of the origin of the capital or whether the firm provides knowledge-intensive services. The second major result is the fairly high percentage of innovative firms and firms having introduced non-technological innovations. A third important innovation pattern is that, on average, the percentage of firm that introduced organizational innovation was always greater than the percentage of firms introducing marketing innovation. In a similar vein, for almost all service sectors, firms introduced more product than process innovations

Concerning non-technological innovation, i.e., organizational and marketing innovations (columns 6 and 7 in Table 3), the service sector and industrial firms exhibit a marginally better tendency to innovate in organizational areas (e.g., marketing). Generally, both sectors exhibit a similar tendency to innovate in technological and non-technological areas. However, the tendencies to innovate differ according to the scale or size of the firm measured by the number of employees. For example, in KIBS firms, 21% of small firms reported achieving a non-technological innovation, whereas for medium and large firms, this tendency was 35% and 42%, respectively. For firms in the manufacturing sector, the tendencies for small, medium and large firms were 16%, 30% and 49%, respectively.

Table 3: Comparing different innovation activities by sectors of industry and services

	size	N*	Product	Process	Tech Innovation	Organizational innovation	Marketing innovation	Non-Tech innovation	Tech and Non-tech Innovation
	1	2	3	4	5	6	7	8	9
All service Industry	All	2,373	16.31	22.67	26.71	21.99	15.55	26.51	34.13
	25-50	1271	9.99	13.92	16.91	12.74	10.22	16.60	22.66
	50-150	380	20.00	26.32	32.11	26.05	15.53	31.31	40.79
	>150	722	25.48	36.15	41.14	36.15	24.93	41.41	50.83
KIBS	All	954	16.35	22.64	25.89	21.59	14.25	25.26	31.97
	25-50	577	8.35	13.69	15.42	12.65	9.53	15.94	20.97
	50-150	137	21.25	31.39	37.96	31.38	14.60	35.03	43.80
	>150	240	29.96	39.17	44.17	37.50	25.41	42.08	51.67
Traditional Services	All	1,419	16.67	22.69	27.27	22.27	16.42	27.34	35.58
	25-50	694	11.64	14.12	18.16	12.82	10.81	17.15	24.06
	50-150	243	19.10	23.46	28.81	23.05	16.05	29.21	39.09
	>150	482	22.70	34.65	39.63	35.47	24.69	41.08	50.41
Industry	All	905	21.21	24.41	30.61	22.43	16.80	27.40	37.57
	25-50	425	10.11	14.11	18.35	12.94	10.35	16.24	23.52
	50-150	176	19.31	25.57	32.95	25.00	17.04	30.68	39.77
	>150	304	37.82	38.16	46.38	34.21	25.66	49.29	55.92

Notes: (*): In the product definition for all cases, it includes both new goods and services
Survey of Innovation and Technological Development in Services EDITS-III (2010-2011) and Industry EDIT IV (2009-2010). (1): size (2): Sample: For all firms. (3): firms with product innovations; percentage of all firms (4): firms with process innovations; percentage of all firms (5): Firms with product process innovations or both; percentage of all firms (6): firms with new organization methods; percentage of all firms (7): firms with new marketing methods; percentage of all firms (8): firms with organizational and/or marketing innovations; percentage of all firms (9): firms with product, process and/or organizational and marketing innovations; percentage of all firms.

Concerning non-technological innovation, i.e., organizational and marketing innovations (columns 6 and 7 in Table 3), the service sector and industrial firms exhibit a marginally better tendency to innovate in organizational areas (e.g., marketing). Generally, both sectors exhibit a similar tendency to innovate in technological and non-technological areas. However, the tendencies to innovate differ according to the scale or size of the firm measured by the number of employees. For example, in KIBS firms, 21% of small firms reported achieving a non-technological innovation, whereas for medium and large firms, this tendency was 35% and 42%, respectively. For firms in the manufacturing sector, the tendencies for small, medium and large firms were 16%, 30% and 49%, respectively.

Table 4: Summary of the variables (means)

Variable/ Size	All service Industry			KIBS			Traditional Services			Industry		
	25-50	50-150	>150	25-50	50-150	>150	25-50	50-150	150	25-50	50-150	>150
Innovation Expenditures (% of firms)	18.0	36.0	43.0	17.0	42.0	42.0	19.0	33.0	43.0	18.0	35.0	45.0
Foreign ownership (%)	1.18	2.36	5.82	1.03	3.65	7.08	0.86	4.11	4.35	1.29	1.64	5.19
Export Dummy (% firms)	7.24	8.16	12.32	4.68	7.30	15.00	9.37	8.64	11.00	12.47	38.07	62.17
Engagement in R&D activities (% of firms)	6.61	11.84	25.21	7.45	18.24	27.50	5.91	8.23	24.07	7.05	22.73	40.79
Stable R&D (% of firms)	39.29	37.77	41.21	32.56	48.00	40.91	46.34	25.00	41.38	40.00	37.50	63.71
Public Support (% of firms)	2.83	6.58	6.37	2.95	6.57	4.58	2.73	6.58	7.26	4.24	7.95	14.14
*Innovation Barriers (% all firms)**												
Financing Constraints (%)												
All	17.85	11.32	9.83	17.33	13.14	7.50	18.29	10.29	10.99	25.41	18.18	13.16
Internal	26.82	21.58	17.59	24.96	21.17	13.33	28.38	21.81	19.71	40.94	36.93	22.37
External	24.86	16.57	14.54	24.78	18.98	11.67	24.93	15.23	15.98	31.53	24.43	18.09
Market Risk	22.97	19.21	17.45	21.84	16.06	17.08	23.91	20.99	17.63	30.35	29.54	22.70
Lack of qualified personnel	19.43	21.32	19.39	19.06	18.98	17.08	19.74	22.63	20.54	31.06	26.14	16.12
Lack of Regulations or standard	11.25	8.95	10.80	9.53	5.84	13.33	12.68	10.70	9.54	10.82	10.79	9.21
Sources of knowledge (% of innovative firms)												
Suppliers as source of information	20.00	26.88	25.25	18.44	20.55	26.67	21.08	30.97	24.54	19.35	18.29	25.13
Customers as source of information	25.22	23.12	25.24	26.95	28.77	25.19	24.02	19.47	25.27	21.77	29.27	28.80
Universities as source of information	6.09	5.91	9.31	5.67	4.11	7.41	6.37	7.08	10.25	0.00	4.87	10.47
Government as source of information	4.06	4.84	2.94	2.12	5.48	1.48	5.39	4.42	3.66	0.81	2.44	4.19
Formal Protection (% of all firms)	1.33	2.37	3.05	1.04	2.19	4.16	1.58	2.47	2.49	1.18	6.82	8.88
Skills (Low) (% of all firms)	89.31	3.05	7.63	87.67	1.37	10.96	91.38	5.17	3.45	92.00	8.00	0.00
Skills (Medium)	46.45	18.65	34.90	51.57	16.87	31.57	43.93	19.52	36.55	44.32	20.31	35.37
Skills (High)	57.85	14.39	27.76	64.16	14.16	21.67	52.21	14.59	33.21	51.14	17.61	31.25

Notes: Source: Own calculations Survey of Innovation and technological development. Services EDITS-II (2008-2009) y EDITS-III (2010- 2011). EDITS II; EDITS-III, Industrial Survey EDIT III (2007-2008) EDIT IV (2009-2010). * It is the sum of values in a Likert scale across the different sources (0 indicating that the firms consider such a source as having no importance and 3 or 4 very important)

These tendencies are similar to the findings of Crespi and Zuniga (2012). In addition, these tendencies can reach nearly 50%, which is a high percentage compared with the tendencies to innovate of firms in developed countries or countries that belong to the Organization for Economic Cooperation and Development (OECD). In most emerging or developing countries, as a result of the practice of technological appropriation or assimilation, innovation is over-counted. Therefore, firms in such countries report higher innovation levels.

Table 4 shows relevant statistics on variable gaps that result when the innovation survey is controlled for firm size. It can be observed that larger firms possess more foreign property, have better exposure to international markets (through exports), display a higher tendency to perform R&D and more frequently use sources of knowledge. However, regarding the type of public financing, the result is different. The KIBS firms that exhibit a higher level of access to this type of support are medium-sized.

In addition, it is important to analyze the difficulties that the firms face as a result of obstacles becoming restrictions that can affect the firm's factors, market factors or factors linked to a lack of information. In Table 4, it can be observed that small firms experience a higher level of exposure to such obstacles. Thus, among KIBS firms, 17% developed an important degree of exposure regarding financial restrictions. The percentage decreased to 7.5% for large firms.

4. Empirical Strategy

The empirical model uses the CDM approach, yet have introduced a novelty: We introduce an initial stage corresponding to stage public funding. At this stage the firms receiving public support to finance their innovations. Therefore we explain in detail each of the stages of the empirical model and its corresponding variables, so soon to present the econometric model used.

4.1 Public Support

This initial stage seeks to establish the determinants of the probability of receiving public support. The probability of receiving this support depends on whether a firm has financial restrictions. Therefore, it is anticipated that firms with greater restrictions have a higher probability of receiving public support. In addition, in the public financing stage, a dummy variable has been included that reflects the importance of the regulatory risk. A dummy variable has also been included that indicates if a firm's R&D activities are stable over time. We have also included specific controls for the firm, such as size, exports and property type. With the goal of using the least number of contemporaneous variables, we have included the exports variable, which is a lagged dummy variable that indicates if a firm achieved a certain level of exports during a previous period. Additionally, we include relative productivity, which is also a continuous lagged variable and which measures the distance in productivity of the firm from the subsector average. The remaining variables are contemporaneous with the dependent variable. This financing stage is described as follows:

Pr(Public Support)= Φ(Finance constrain, lack regulation, relative productivity(t-1), stable R&D, formal protection, foreign ownership, exports dummy (t-1), size, sectoral dummies).

Financial support for innovation is by now a common practice at the national and local levels in most advanced economies. The main argument behind that is related with market imperfections. Thus the public interventions arise since firms are not able invest money in high risk projects and they access to external funds is limited. As a result, an underinvestment in innovation activity arise.

In Colombia, the number of institutions that have been supported the Science Technology and Innovation system has increase significantly in the last 10 years. The policy tools follow a process based on the promotion of innovation thought some institutions and regulation in the National Innovation System. One of the policy tools available is related with subsidies from local and national founds.

Various studies have examined the effects of subsidies on the R&D decisions of firms, particularly on the possible additional or substitution effect of public support on private R&D spending. Several analyses (Tello, 2015; Busom et al., 2014; Berubé and Mohnen, 2009) demonstrate that the reaction of the sectors to obtaining support for innovation is not uniform and that whereas in certain cases a positive effect occurs, the effect in other cases is limited.

4.2 Innovation Decision and Intensity

This stage intends to capture the determinants of the decision to pursue and invest in innovation (i.e., intensity). Innovation intensity is understood as all of a firm's expenditures on science and technology, whereas the innovation decision is a discrete variable that reflects the innovative status of a firm. This variable will be activated when a firm exhibits any positive spending on innovation activities.

The stage of determining to invest in innovation is described as follows:

Pr(Innovation Decision)= Φ(innovation intensity(t-1), Public support (predicted), formal protection, market risk, foreign ownership, exports dummy (t-1), relative productivity(t-1), skills(medium, high), size, sectoral dummies).

Log(Innovation Intensity)= f(innovation intensity(t-1), Public support (predicted), source of information (Suppliers, Customers, Institutional), foreign ownership, exports dummy (t-1), skills(medium, high), size, sectoral dummies)

The variables included in this stage concern specific factors of the firm, such as the type of foreign property, exports, firm size, skilled workers and sectoral dummies. These variables are included in the innovation decision and intensity. It is important to note that the export variable is a lagged dummy that indicates if the firm achieved a certain level of exports during the previous term. The skilled worker variable is a lagged dummy that is activated when more than 40% of a firm's workforce has superior and/or technological training levels. The remaining variables are contemporaneous with the innovation decision and intensity.

Additionally, we introduce a change with respect to previous studies: the inclusion of a lag of innovation intensity as an explanatory variable. We include this variable because of the long-term nature of many innovation projects. That is, if a firm spent resources during a certain year, it should have a greater flow of resources for this purpose during the subsequent year. It is anticipated that a persistent dynamic occurs in innovation projects.

Next, we have included the probability of receiving public support as a predicted variable in the public financing stage. We include this variable because it accurately predicts the decision to spend. It has also been included in innovation intensity in a manner that enables the variable to evaluate if public support contributes to increase spending on innovation. Thus, it is anticipated that public support positively affects the innovation decision and innovation intensity.

The variables included in the innovation decision (but not in innovation intensity) concern the obstacles to carrying out innovation projects, such as market risk and the lack of qualified personnel. In addition, formal protection of innovations has been included. These exclusion restrictions operate in the sense that the innovation obstacles affect the innovation decision but do not influence spending (i.e., intensity). The same occurs with formal protection. Regarding the variables that are only included in the innovation intensity equation, we have included the sources of information. These sources involve categorical variables that concern the offer conditions of suppliers, clients, public and private universities and public research institutes.

4.3 Innovation Production Function

At this stage we tried to capture the connection between the inputs (spending or intensity of innovation) and the outputs of the innovation process. The production innovation function has to do with variables result of the innovation process (product innovations, process, marketing or organizational either new to the market or the company).

This step is explained by the intensity of innovation predicted from the previous stage of the CDM model. At this stage the firm-specific variables (i.e., exports, the foreign ownership share (as dummy), company size and sector dummies) appear. Additionally we have included the sources of knowledge, therefore the fact whether suppliers, customers and public institutions (public and private universities and public research institutes) have been important as suppliers of ideas for innovation. This stage is described below:

*Pr(Innovation Output)= **Φ**(Predicted Log-innovation intensity, Public support (predicted), formal protection, source of knowledge (Suppliers, Customers, Institutional), skills(medium, high), foreign ownership, exports dummy (t-1), size, sectoral dummies)*

4.4 Labor Productivity

The final stage of the model seeks to explain labour productivity (i.e., sales/per employee) using the predicted variables of the innovation of processes, products, organizational innovations, marketing and R&D. In addition, the skilled workers variable is included as a dummy that represents the professional training of the workforce (i.e., a proxy of human capital). In this stage, we also control (using specific variables) for the firms included in the previous stages (i.e., the exports dummy, property type and firm size). The exports dummy appears to be lagged during one period, whereas the property type and firm size are contemporaneous with the productivity level. Finally, we include sectoral dummies, given that we do not know the intensity of capital.

> *Log(Labour Productivity)=f(predicted innovation outcomes, skills(t-1), foreign ownership, exports dummy (t-1), firm size, 1-digit industry dummies)*

Thus, the model includes four sets of relationships for study: public financing, the equation of the innovation decision and the innovation intensity linked to their determinants, the equation of innovation that links investment to innovative success and, finally, the relationship of productivity that associates innovation with the production of the firm. A summary of each stage is presented in Table A3. In Table 6, an adopted identification strategy is presented.

Thus, the analysis emphasizes that what affects productivity is not the input in innovation (i.e., innovation spending or intensity) but coping with innovation in and of itself. Thus, firms invest in innovation with the objective of developing innovations in product, process, marketing or organization that can contribute to their productivity and produce other economic results.

Table 6: Identification Strategy

Variables	Public Support	Propensity to invest in innovation	Innovation Intensity	Innovation Production	Output production
Selection Term			x		
Predicted Public Support		x	x		
Predicted Log-innovation intensity				x	
Predicted Innovation Outcomes					x
Investment intensity (t-1)		x	x		
Exports dummy (t-1)	x	x	x	x	x
Foreign Ownership	x	x	x	x	x
Obstacles					
Financial Constraint	x				
Lack of regulation	x				
Market risk		x			
Stable R&D activities	x				
Formal protection	x	x		x	
Relative Productivity (t-1)	x	x			
Sources of information					
Suppliers			x	x	
Customers			x	x	
Institutions			x	x	
Skills(medium, high)		x	x	x	
Skills (t-1)					x
Size	x	x		x	
Industry fixed effects (1 digit)	x	x	x	x	x

*Product innovation, process innovation, organizational and marketing innovation. All of those variables are dummies output variables.

5. Econometric Approach

The model is estimated for all firms. The reason to use data from all of the firms is that all of the firms exercise a certain effort to innovate, although not all report a level of innovative effort. The model consists of a system of four equations. The first equation corresponds to the public financing stage. The second part includes three equations: one for the decision to innovate, another for innovation intensity and, finally, an equation that relates innovation input and output. The fourth equation concerns the relationship between the design of the firm and the effects of innovation. Each equation requires a distinct econometric treatment.

- **Public Support stage**

Given the possible endogeneity between the decision to innovate and public support, the latter is investigated in a previous stage (i.e., the public financing stage). It is worth highlighting that the decision to innovate depends on the existence of public policies that promote innovation. Thus, we wish to demonstrate if public support for innovation (i.e., direct subsidies) affects the decision to innovate. Equation (1) models this behavior.

$$Pr[PS_i = 1] = Pr(Public\ Support) = Pr[\sum x_{0i}\beta_0 + \varepsilon_{0i}] \qquad (1)$$

where PS identifies a dummy variable that assumes the value of 1 if the firm reports having obtained a subsidy for innovation[6]. It is worth noting that the survey does not provide information on whether the firm applied or did not apply for direct support. What the survey reveals is the decision to apply for public support on behalf of the firm, which reveals the preferences of the public agency.

This stage is modelled by performing a probit estimation (estimated by maximum likelihood) for the entire sample of firms. The predicted value of the probability of receiving public support is included in the following stages of the model.

- **Innovation Decision and Intensity**

Given that a minority of firms implement innovations of a formal nature, innovation spending is a dependent censured variable. Thus, estimations through standard methods of regression deliver inconsistent estimations. Therefore, bearing this problem in mind, we estimate this group of equations using a generalized Tobit model proposed by Heckman (1979, 1980).

The strategy is to estimate the probability that a firm will achieve innovation and then, according to this probability, to estimate the intensity determinants (i.e., spending on innovation). Consider equations (2) and (3):

$$g_{01} = \begin{cases} 1 & if \quad g^*_{0,i} = \sum x_{1i}\beta_1 + \varepsilon_{1i} > \tau \\ 0 & if \quad g^*_{0,i} = \sum x_{1i}\beta_1 + \varepsilon_{1i} \leq \tau \end{cases} \qquad (2)$$

$$r_i = \begin{cases} r^*_i = \sum x_{2i}\beta_2 + \varepsilon_{2i} & if \quad g_i = 1 \\ 0 & if \quad g_i = 0 \end{cases} \qquad (3)$$

[6] This definition only subsidies included, excluding loans, tax incentives or public-private contracts. In turn, the survey does not distinguish whether funding is regional or local.

where g_i^* is the latent variable of the decision to innovate and g_i is the indicator of the variable, which is equal to 1 if the firm reports innovation spending. However, this decision is possible if and only if the firms invest in science and technology innovation activity[7]. However, given that there is a fixed cost for innovation spending, it is possible that many values are between a value close to zero and the fixed cost of innovation, for which many values will not be present in the sample. Therefore, equation (2) cannot be directly estimated without considering selection bias and truncation. This difficulty can be resolved by adhering to a selection equation that indicates if the firm performed innovation activities. Intuitively, this method resolves the problem of selection as a specification problem (variable problem omitted).

This variable expresses a criterion for decision making, such as the present value of benefits expected by achieving an innovation. A firm invests in innovation if g_i^* is positive or greater than the constant threshold (denoted by τ). The variables r_i and r_i^* are the variables of intensity of the observed innovation spending (current) and the latent innovation spending, respectively. These two variables are expressed in thousands of fixed value Colombian pesos by worker (in logarithms).

Equations (2) and (3) are jointly estimated as a generalized Tobit whose estimation is performed by maximum likelihood. Given that r_i^* is only observed when g_i^* is greater than a minimum threshold, it is necessary to specify its distribution together with the objective of obtaining an estimable model. For the terms of error, ε_{1i} and ε_{2i} are assumed to be distributed on behalf of a normal joint distribution with an average of zero, as expressed in (4).

$$\binom{\varepsilon_{1i}}{\varepsilon_{2i}} \overset{iid}{\rightarrow} N\left(\binom{0}{0}, \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_1^2 \end{pmatrix}\right) \tag{4}$$

where σ_1 and σ_2 are standard errors of ε_{1i} and ε_{2i} and ρ is the correlation coefficient.

- **Innovation production function**

In this stage, four defined models for dummy variables are estimated that reflect the innovation output (i.e., product, process, marketing and organizational innovation). These equations are expressed in a general way in (5) and represent an innovation function whose exact formulation depends on whether the innovative output of the firm is approximated by the fact that a certain type of innovation is introduced. In this case, the firms are examined according to whether they introduced certain types of product, process, marketing and organizational innovation. The firms were coded as 1 if the response was affirmative and zero if there was a different response. Thus, this specification estimates the effects of a set of explanatory variables on the probability that a firm reports a type of product or process innovation activity.

[7] This variable includes all cost (Own research, training, external R&D, knowledge embodied in the new machinery and software.

$$I_i = Pr[r_i^* > 0] = Pr[\alpha_I r_i^* + \beta_3 x_{3i} + \varepsilon_{3i}] \quad (5)$$

The equations for each innovation output are separately estimated using a probit model[8], in which the potential use of different types of innovation is considered. Under this function, it is assumed that the production of new knowledge depends on the current (or past) investment in new technology (i.e., current or past investment in innovation). In addition, it is assumed that the term of error follows a multivariate normal distribution.

Different from other innovation studies, our approach estimates each innovation output separately because high collinearity exists between the innovation product and process. Many of the firms that introduce product innovations simultaneously introduce process innovations. Therefore, it is difficult to empirically separate the products of the process innovations. Thus, if we do not separate them, identification problems can occur when we gather these variables in the previous stage (i.e., the productivity equation). In this case, we prefer to be more conservative and separately estimate each model.

- **Productivity equation**

This equation is described in (6).

$$\mathrm{y_i} = \alpha_0 + \alpha_\mathrm{I}\mathrm{I_i} + \beta_4 \mathrm{x}_{4\mathrm{i}} + \varepsilon_{4\mathrm{i}} \quad (6)$$

The variable $\mathrm{y_i}$ is the log of productivity (sales per employee[9]). Where $\varepsilon_{6\mathrm{i}}$ is a random disturbance term. $\mathrm{I_i} = \mathrm{Pr}[\alpha_\mathrm{I}\mathrm{r_i^*} + \beta_3\mathrm{x}_{3\mathrm{i}} + \varepsilon_{3\mathrm{i}}]$ which comes from the innovation production function (equation 5).

$$\mathrm{y_i} = \alpha_0 + \alpha_\mathrm{I}\mathrm{Pr}[\alpha_\mathrm{I}\mathrm{r_i^*} + \beta_3\mathrm{x}_{3\mathrm{i}} + \varepsilon_{3\mathrm{i}}] + \beta_4 \mathrm{x}_{4\mathrm{i}} + \varepsilon_{4\mathrm{i}} \quad (7)$$

First, the final equation (7) is estimated using least squares and innovation output variables are instrumented in order to take into account the input variables endogeneity innovation. In turn, the explanatory variables may vary depending on whether the decision to invest in innovation or as try to predict spending (or intensity) in innovation, conditional to a positive investment decision. In this case, the coefficient α_I is the elasticity of productivity with respect to the output of innovation, while β_4 is specific controls to firms previously explained.

Second, we use another estimation method to estimate the productivity equation (It is called quantile regressions). Let assume that the quantile θ of the conditional distribution at the level of productivity (sales per worker) (y_i) is lineal in x_i and rewriting equation (7), the conditional quantile regression model is defined from equation (8).

[8] The estimation of product and process innovations is done separately there is a high collinearity between these two variables (approximately 80%, see Appendix Table A6).
[9] In different studies other indicators of job performance are used. In the case of Colombia, there is no information on the value added. Therefore sales of each company will be used.

$$Q_y(\tau|X) = Q(\mathrm{y})_{i,q} = \beta_{1q} Pr[\alpha_I r_i^* + \beta_3 x_{3i} + \varepsilon_{3i}] + \beta_{4q}(\beta_4 x_{4i})_i + \mu_{i,q} \quad (8)$$

Given a $\tau \in (0,1)$ and the productivity (y), the τ^{th} quantile is shown in (9).

$$Q(\tau) = inf\{y_i : F(y_i) \geq \tau\} \quad (9)$$

Where F is the distribution function of sales per worker y_i.

For each Beta, the null hypothesis of equal coefficients along the quantile distribution must be verified, which is done using the Wald test. For the proposed model, the null hypothesis should be rejected. For more detail, see Koenker and Hallock (2001). The properties of equations (8) and (9) are as follows:

1. It is assumed that the conditional innovation quantiles $Q_y(\tau|X)$ are the inverse of the function of conditional cumulative distribution of sales per worker $F_y^{-1}(\tau|X)$, where $\tau \in (0,1)$ represents the different quantiles of productivity[10].

2. $Quant_\theta(\widehat{y}_i|x_{i,})$ is defined as the θ^{th} quantile of y_i, conditional on the regressor vector x_i; β_θ is the vector of the parameters to be estimated for different values of θ in $(0,1)$.

3. In this case, the parameters of the model are identified in (8), assuming a quantile regression (QR, for the purposes of this document), which is a semi-parametric method used because it does not suppose a form of probability distribution for the random part of the model μ[11].

4. In order to obtain estimators that are robust in the face of phenomena such as the heterogeneity derived from the sample of firms, and the heteroskedastic nature of the problem, the QR can be presented as an appropriate estimator. Therefore, the population is divided into quintiles, deciles, or any type of strata distribution where percentiles or fractiles refer to the general case (Koenker and Hallock, 2001).

5. In equation (6), μ_θ is the error term representing a continuous and differentiable function $F_{\mu\theta}(\cdot\,|x)$ and a density function $f_{\mu\theta}(\cdot\,|x)$, where $F_i(\cdot\,|x)$ is the function of conditional distribution[12]. From (6) it is deduced that $Quant_\theta(\mu_{\theta i}|x_i) = 0$.

From the preliminary empirical findings in figure 2, shows a "growing" relationship between productivity by firm and firm size can be observed, which reflects a model of quantile regression, which is optimal given that there is a level of limitation of the sample. This indicates that the

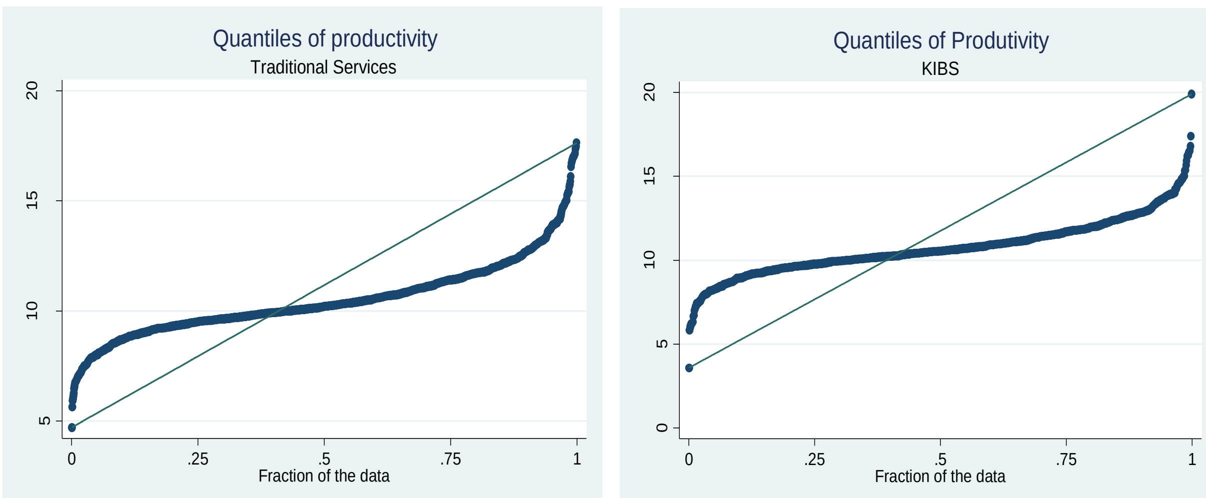
[10] For Example, $\tau = 0.5 \therefore Q_y(0.50|X)$ is the 50th percentile of the distribution "Y" conditional on the values of "X". In other words, 50% of values of "Y" are equal to or less than the specified function of "X".

[11] Quantile regression provides the opportunity for a comprehensive view of statistics and the relationship between stochastic variables. Just as minimizing the sum of squares allows the estimation of a variety of models for conditional mean functions, minimizing a simple asymmetric version of the absolute errors can be estimated by conditional quantile functions (Kameron and Trivedi, 2005).

12 If θ varies from 0 to 1, you can get the complete distribution "y" conditional on "x".

distribution has different coefficients, like a piecewise continuous function, since there are different means and variances conditioned by the quantiles. That is, the effect of the explanatory variables on the determined variable is higher in the upper quantiles, so it has an effect that is not homogeneous. On balance, quantile regression allows the parameters of interest to vary based on unobserved factors. Some firms have higher underlying labor productivity and we are interested in the innovation premium for these firms and, separately, the premium for less productive firms.

Figure 2: Quantiles of Productivity for KIBS and Traditional Services



Thus, it is imperative that we focus on the distribution of productivity. If we follow the standard approach in the literature and regress the log of productivity on an innovation predicted outcome and a set of control variables (including industry fixed effects) using ordinary least squares (OLS), there is no room for firm heterogeneity of this kind. OLS estimates the average effect over the entire distribution. This summary statistic, however, may not be representative of the relationship between innovation and productivity at any part of the productivity distribution. If the exporter premium is positive only at the top of the productivity distribution. Yet, the mean productivity premium would still be positive.

It should be noted that as in other studies of this cut, our estimate of the CDM model has had some modifications. First, we do not use patent data as the initial estimates of Griliches (1979) y Crepon., et al (1998) did. This is because the patent information is somewhat irrelevantly in a sample of countries like Colombia, where a small fraction of firms innovate at the level of the technological frontier.

In addition to all the estimates we decided to include a set of sectoral dummy variables to single digits in order to capture specific effects at the sector level. Finally, we differ from that proposed by Griffith et al. (2006) using the main explanatory variables. We made the investment in innovation as a measure of investment in knowledge, rather than investing in R&D. Our variable is much more comprehensive because it includes all actions that firm take to implement concepts, ideas and methods to acquire, assimilate and incorporate new knowledge [13]. This variable includes expenditures on design, installation of new machinery and equipment, design, marketing and training.

Finally, the estimate of the productivity equation through quantile regressions have been used in other papers trying to assess the effect on exports for more productive and less productive firms[14]. The literature has previously recognized that quantile estimates are interesting in this context. Furthermore, many papers in the literature have understood the potential importance of conditioning on enterprise fixed effects to account for unobserved firm-level characteristics. However, there is a little empirical evidence of the effect of innovation on productivity using this approach.

6. Results

6.1 Public Support Determinants

It is found that for traditional services and manufacturing sector the presence of so many domestic financial constraints (own company)) and external, increases the likelihood of using public support in about 5 percentage points (pp) and 3 pp respectively. This variable is not statistically for the KIBS sector. On the other hand, regulatory barriers are only statistically significant for KIBS companies. These results are consistent with the patterns found in the stylized facts, which has found that the main barrier to innovation activities is financial constraint.

With regard to the stability of R&D activities performed by the company, it positively affects the likelihood of access to public support by 9 percentage points for enterprises in the traditional service sector. This same effect is 7 percentage points for enterprises in the KIBS sector. This can be explained by the signaling throw on the market by those companies that have long-lasting experiences of research and development activities. This could define an effort of these companies to develop innovation projects and at the same time an effort by the public sector to give priority to those most stable companies.

[13] Otros trabajos también utilizan este tipo de variables (por ejemplo Loof and Heshmati, 2006; OECD, 2009).
[14] This kind of studies have been applied in the International Studies. See Serti and Tomasi (2009), Haller (2012), Wagner (2011), and more recently Powell and Wagner (2014).

Table 7: Public Support Stage

VARIABLES	(1) Traditional	(2) KIBS	(3) Industry
Financial Constrains	0.0387***	0.0159	0.0578***
	(0.0132)	(0.0146)	(0.0253)
Lack of Regulation	0.01325	0.0455***	0.0126
	(0.0133)	(0.0147)	(0.0193)
Formal protection	0.0230	0.0733**	0.0338
	(0.0338)	(0.0336)	(0.0333)
Stable R&D	0.0855***	0.0567***	0.0998***
	(0.0197)	(0.0255)	(0.0277)
Exports Dummy (t-1)	0.0095	0.0158	0.0288
	(0.0234)	(0.0244)	(0.0213)
Foreign Ownership	-0.0093	(note)	0.0078
	(0.0354)		(0.0375)
Relative Productivity (t-1)	-0.0313	-0.0211	0.0799
	(0.0353)	(0.0218)	(0.0614)
50<Size<250	0.052***	0.0194	0.0227
	(0.0179)	(0.0194)	(0.0277)
Size>250	0.0422***	0.0071	0.0271
	(0.0183)	(0.0237)	(0.0292)
Industry fixed effects (1 digit)	Yes	Yes	Yes
Observations	1,419	926	905
LR Chi2	65.20***	44.76***	61.58***
Log Likelihood	-283.552	-154.6108	-239.637
Pseudo R2	0.1031	0.1265	0.1139

Notes: Each column shows estimated average marginal effect. Method: Probit. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. (Note) This variables is dropped because predicts failure perfectly. The number reported are the marginal effects. Robust Standard errors are computing with Delta-Method

6.2 Determinants of innovation Intensity and decision

In table 8, we present the findings from the second stage of the CDM model. The selection equation for engaging in innovation activities is shown separately for different sector. Thus the results correspond to the estimated equations (2) and (3) which are jointly estimated by Tobit type II.

Table 8: Probability of Investing in innovation and Intensity of Innovation per employee

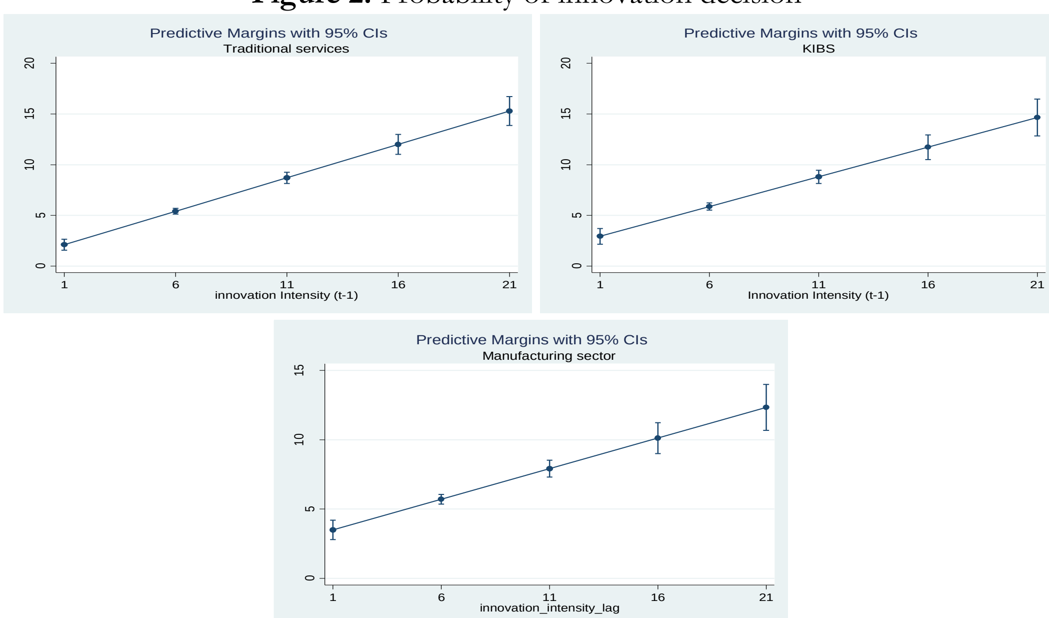
	Traditional Services		KIBS		Industry	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Intensity	Decision	Intensity	Decision	Intensity	Decision
Public Support (Predicted)	1.127	0.536**	3.485**	0.868**	1.0767	1.292***
	(1.393)	(0.250)	(1.728)	(0.389)	(1.2717)	(0.312)
Innovation Intensity (t-1)	0.650***	0.1032***	0.589***	0.110***	0.4728***	0.105***
	(0.048)	(0.006)	(0.0703)	(0.0085)	(0.0556)	(0.0075)
Export Dummy (t-1)	0.036	-0.0028	-0.4322	-0.0197	-0.5837***	-0.0383
	(0.338)	(0.047)	(0.474)	(0.0654)	(0.2859)	(0.0461)
Foreign Ownership	0.333	0.109	0.0508	-0.0642	0.8847**	0.0817***
	(0.490)	(0.073)	(0.6297)	(0.1232)	(0.4538)	(0.0837)
External as source of information	0.066		0.1848		0.2623	
	(0.189)		(0.2702)		(0.2466)	
Institutions as source of information	-0.199		-0.2433		0.1399	
	(0.215)		(0.3338)		(0.2678)	
Skills Medium (t-1)	-0.453	-0.122		0.2948	-0.4345	0.3535*
	(0.612)	(0.099)		(0.1087)	(1.245)	(0.196)
Skills High (t-1)	-0.607	-0.144		0.0091	0.079	0.311*
	(0.625)	(0.095)		(0.100)	(1.261)	(0.187)
Formal Protection		0.157*		-0.1021		-0.0771
		(0.0908)		(0.1402)		(0.0853)
Market Risk		0.053***		-0.0357		-0.0208
		(0.0246)		(0.0325)		(0.0347)
Relative Productivity (t-1)		-0.0255		-0.1478		-0.3689**
		(0.0804)		(0.0965)		(0.1662)
Size		0.0581***		0.0691***		0.05443**
		(0.009)		(0.0114)		(0.01891)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,419		926		905	
Censored Obs	999		684		628	
Uncensored obs	420		242		277	
Wald Test of Independence (rho=0).	44.00***		88.86***		86.06***	

Notes: Each column shows estimated average marginal effect. Method: Heckit likelihood. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The number reported are the marginal effects. Significance tests with bootstrapped standard errors (Bootstrap replications= 50)

First, regardless of the technological level of the industry, there is a remarkably similarity in the signs of coefficients across results for both equations. This is particularly true for the decision to invest, where all the signs were the same although the statistical significances differ. Regarding public support, these seem to be a determining that positively affects the decision to innovate in the traditional and manufacturing sector. At the same time, it appears that this variable does not explain the intensity of innovation. It means that the use of subsidies as instrument for innovation increases the probability that firms decide to invest in innovation but does not increase the size of the investments. Previous empirical evidence shows that this variable is significant and also explains the intensity of spending on innovation in the service sector (Mairesse and Robin, 2010; Vahter, et al. 2011). The results for Colombia can be explained by the low participation of firms in this type of instruments to promote innovation. As seen previously, only 5% of companies use this tools.

Second, regarding the effect of the one lag of innovation intensity on the probability of investing in innovation, it is confirmed that for firms of the traditional services, KIBS and manufacturing sector, this variable has a positive effect on the decision to innovate. Figure 2 shows the estimated intensity for different values of innovation intensity for each sector. Low innovation intensity values are likely to invest close to 2% and the probability for high values is above 15%. The average marginal effect is 10% for each sector. This result is very important since it signals, as we will comment later, that some kind of persistency is present for firms undertaking innovation investment decision.

Figure 2: Probability of innovation decision-



Third, there are some interesting differences to note, on the one hand exports and foreign ownership structure do not appear to affect the decision process innovation and the intensity of spending in KIBS Companies. At the same time, exports has a negative effect on innovation intensity for manufacturing companies. One potential reason is that exporting firms might have been exporting for a long period of time and they need to maintain their innovation expenditure to keep competing in those more demanding markets. After being persistent exporters, to satisfy external clients' demands for innovative goods, they need to keep up their investment standard. It may be that persistent exporters are also persistent innovators (from the output side of the innovation process). A longer span of innovation data is needed to test this explanation. This is similar to the findings of Vahter and Masso (2012).

The indicator of obstacles to innovation (market risk) is not significant. Only the variable "market risk" has a significant effect on innovation decision in traditional services. This finding is the same as Vahter and Masso (2012), Stelios and Aristotelis (2009), have found. These results may simply reflect the fact that innovative firms may be more aware of innovation obstacles, and thus, more likely to report these hampering factors as important for the firm. However, there is a little empirical evidence about the impact of barriers on innovation decision.

Finally the different source of knowledge as determinants of innovation investment are consider important for the manufacturing firms, but considered unimportant for services companies. It appears that the external source of knowledge (consumers and suppliers) do not have an important role for expending in innovation. Maybe it implies that these channel are not being considered as sources of financial opportunities to innovation activities.

6.3 Innovation Production Function.

After analyzing the determinants of spending on innovation, we want to continue the analysis with the following aspect of the innovation process. This stage is related to the results of that process rather than inputs. As mentioned, the determinants will be reviewed for a particular firm reported having introduced new products and processes as well as the variables that explain the organizational and marketing innovations. Tables 9 and 10 outline the results of the estimation and show the impact of the determinants of the likelihood of having made some product, process, marketing or organizational innovation respectively over the period considered. The coefficients in those tables show marginal effects of explanatory variables, estimated at the sample mean. As was explained in the CDM model, the predicted values for innovation investments are obtained from the previous stage—the innovation intensity equation (stage 2).

The first finding we would like to highlight is the positive and significant impact of investments in innovation outputs. We find the effect of innovation investments is especially large in manufacturing companies. While the smaller impact of innovation expenditure on innovation output in service sector comparing with industry companies, is in line with Peters et al. (2014); Arvanitis (2008). Given that product innovation are more linked to the technology used and would be more likely to result from formal innovation activities, the lower correlation for services in our regression is unexpected. It has been noted in the literature that in services is more difficult to appropriate amount of innovation investment due to less information for predicting financial returns (Himmelberg y Petersen, 1994; Hall, 1996).

Table 9: Innovation production function (Product and Process innovation)

VARIABLES	Product			Process		
	Traditional (1)	KIBS (2)	Industry (3)	Traditional (4)	KIBS (5)	Industry (6)
Innovation Intensity (Expenditure per employee) (Predicted)	0.0345***	0.0315***	0.0684***	0.0475***	0.0435***	0.0772***
	(0.0047)	(0.0069)	(0.0069)	(0.00455)	(0.0053)	(0.00702)
Externals as source of information	0.1547***	0.1532***	0.1245***	0.205***	0.1906***	0.1788***
	(0.0185)	(0.0299)	(0.0273)	(0.0197)	(0.0210)	(0.0238)
Institutions as source of information	0.0800***	0.0591**	0.0569**	0.0323	0.0557	0.0365
	(0.0261)	(0.0313)	(0.0308)	(0.0306)	(0.0408)	(0.0341)
Exports Dummy (t-1)	-0.0087	0.0126	0.0507**	-0.0047	0.0144	0.0313
	(0.0285)	(0.0344)	(0.0218)	(0.0317)	(0.0452)	(0.0264)
Foreign Ownership	-0.1182**	-0.0416	-0.0089	-0.0283	-0.201	-0.0689
	(0.0512)	(0.1112)	(0.0408)	(0.0475)	(0.318)	(0.0474)
Formal Protection	0.1114***	0.0127	0.0472	0.0411	0.0390	0.0362
	(0.0399)	(0.0762)	(0.0493)	(0.0475)	(0.0878)	(0.0481)
Skills Medium (t-1)	0.8092***	0.0042	0.645***	-0.0213	-0.0067	0.7348***
	(0.0184)	(0.0352)	(0.0575)	(0.0606)	(0.0418)	(0.0618)
Skills High (t-1)	0.8217***	-0.0121	0.623***	-0.0444	-0.0213	0.6936***
	(0.0620)	(0.0385)	(0.0618)	(0.0574)	(0.0455)	(0.0689)
Size	0.0090**	0.0217***	0.0184***	0.0300***	0.0229***	0.0059
	(0.0044)	(0.0043)	(0.0063)	(0.00491)	(0.00465)	(0.00810)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1419	926	905	1419	926	905
Wald c2	857.30***	290.94***	704.35***	467.98***	187.21***	689.81***
Log pseudo likelihood	-440.894	-244.886	-288.481	-508.434	-299.617	-297.611
Pseudo R2	0.3024	0.393	0.4003	0.3309	0.3864	0.4084

Notes: Each column shows estimated average marginal effect. Method: Probit. *Significant at 10%, **significant at 5%, ***significant at 1%. The number reported are the marginal effects, and the corresponding standard errors in parenthesis. Significance tests with bootstrapped standard errors (Bootstrap replications= 50)

Table 10: Innovation production function (Marketing and Organizational innovation)

VARIABLES	Marketing			Organizational		
	Traditional (1)	KIBS (2)	Industry (3)	Traditional (4)	KIBS (5)	Industry (6)
Innovation Intensity (Expenditure per employee) (Predicted)	0.0338***	0.0208***	0.0474***	0.0341***	0.0311***	0.0569***
	(0.004)	(0.0051)	(0.0075)	(0.0056)	(0.0064)	(0.0099)
Externals as source of information	0.1653***	0.1625***	0.142***	0.2196***	0.2144***	0.1864***
	(0.0156)	(0.0219)	(0.0260)	(0.0210)	(0.0252)	(0.0304)
Institutions as source of information	0.0972***	0.0602*	0.0865***	0.1165***	0.0839**	0.0605*
	(0.0226)	(0.0371)	(0.0288)	(0.0319)	(0.0368)	(0.0376)
Exports Dummy (t-1)	-0.0215	0.0323	0.0168	-0.0188	-0.0327	0.0253
	(0.0288)	(0.0419)	(0.0247)	(0.0278)	(0.0428)	(0.0232)
Foreign Ownership	-0.0634	0.180	-0.1152**	-0.0787	0.1876	-0.0332
	(0.0492)	(0.113)	(0.0593)	(0.0609)	(0.1143)	(0.0651)
Formal Protection	0.1003**	-0.0010	0.1033***	0.0578	-0.0207	0.1239**
	(0.0482)	(0.0544)	(0.0385)	(0.0526)	(0.0658)	(0.0526)
Skills Medium (t-1)	-0.0772**	-0.0459	0.6705***	-0.0039	0.0514	0.8049***
	(0.0369)	(0.0336)	(0.0565)	(0.0659)	(0.0464)	(0.1033)
Skills High (t-1)	-0.0840**	-0.0676	0.6171***	-0.0001	0.0239	0.7975***
	(0.0369)	(0.0298)	(0.0617)	(0.0662)	(0.0400)	(0.1060)
Size	0.0203***	0.0122***	0.0057	0.0307***	0.0256***	0.0059
	(0.0035)	(0.0052)	(0.0079)	(0.0040)	(0.0043)	(0.0077)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1419	926	905	1419	926	905
Wald c2	543.57***	262.93***	739.09**	559.95***	320.57***	350.93***
Log pseudo likelihood	-412.963	-263.637	-280.020	-495.778	-291.306	-323.317
Pseudo R2	0.3483	0.2769	0.3164	0.3411	0.3905	0.3289

Notes: Each column shows estimated average marginal effect. Method: Probit. *Significant at 10%, **significant at 5%, ***significant at 1%. The number reported are the marginal effects, and the corresponding standard errors in parenthesis. Significance tests with bootstrapped standard errors (Bootstrap replications= 50)

One of the most interesting results is related to the sources of knowledge used by companies. We note that suppliers and customers as sources of information, are positively correlated with the probability of being innovator (product and process innovations) in the service sector (for KIBS and non-KIBS companies), but it do not occurs in manufacturing firms. Meanwhile, institutions as sources of information, do not explain the probabilities of being innovator (for product and process innovation output) in the KIBS sector. This is not the case for marketing and organizational innovations where these two sources of knowledge positively explain the probability of being innovator for traditional and KIBS companies. Regarding other characteristics of firms, the results show that neither the export coefficient or the type of ownership (foreign capital) nor the skills, are statistically significant to explain the innovations in most sectors, while formal protection of innovations are only significant for traditional services companies.

Regarding with the size, we have found that large firms have a higher propensity to innovate than smaller ones, a result that holds for both KIBS and no-KIBS firms in all of the innovation types. Previous studies of European countries (Mairesse and Robin, 2009; Musolesi and Huiban, 2011) also found a positive impact of size on service firms' decision to innovate. Finally, our results emphasize the selectivity issue, as the inverse Mills' ratio, included to correct for potential sample selection, is significant in both the output and the productivity equation.

6.4 Innovation effects on Labor Productivity

The final stage of the model, which relates the labor productivity of firms to their innovation indicator, is shown in table 11. We have controlled by the qualifications of the labor (skills) and the sectoral fixed effect as proxy of working capital. We have also controlled by the firm specific factors such as the type of property and exports[15]. We have also adhered the estimating innovations outputs of the previous stage separately.

Earlier studies usually show that product innovation is positively associated with productivity of firms in the service sector. However, this effect tends to be smaller than in manufacturing industry. The large-scale study of OECD (2009) based on CDM approach for 18 different advance economies, have found that in most countries the productivity effect on innovation was larger in manufacturing sector than in services. At the same time, countries like Australia, Denmark and Finland, product innovation was not statistically significant associated with labor productivity of service firms.

[15] In table A7 (appendix) you can find a correlation matrix between the explanatory variables for this stage.

Table 11: Productivity Equation

Variables	Dependent Variable (Log (Sales per employee)											
	Traditional Services				KIBS				Manufacturing			
Predicted Product Innovation Output	0.3257** (0.163)				0.153 (0.205)				0.702*** (0.188)			
Predicted Process Innovation Output		0.1461 (0.160)				0.054 (0.187)				0.637*** (0.169)		
Predicted Marketing Innovation output			0.273* (0.160)				0.235 (0.273)				0.859*** (0.191)	
Predicted Organizational Innovation output				0.056 (0.162)				0.027 (0.190)				0.728*** (0.147)
Exports Dummy (t-1)	0.6909*** (0.1574)	0.697*** (0.181)	0.692*** (0.162)	0.703*** (0.158)	0.399** (0.196)	0.407** (0.218)	0.394** (0.183)	0.410** (0.203)	0.701*** (0.108)	0.734*** (0.092)	0.740*** (0.081)	0.727*** (0.090)
Foreign Ownership	0.7408*** (0.242)	0.708*** (0.230)	0.715*** (0.265)	0.7224*** (0.307)	0.487** (0.218)	0.492** (0.217)	0.472** (0.220)	0.488** (0.218)	0.628*** (0.204)	0.684*** (0.191)	0.730*** (0.192)	0.662*** (0.205)
Skills (t-1)	0.4259*** (0.085)	0.4341** (0.078)	0.4319*** (0.076)	0.433*** (0.088)	0.745*** (0.109)	0.744*** (0.122)	0.745*** (0.106)	0.744*** (0.095)	0.471*** (0.082)	0.473*** (0.081)	0.492** (0.075)	0.466 (0.066)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,396	1,396	1,396	1,396	926	926	926	926	902	902	902	902
Wald chi2	979.16***	732.09***	915.39***	1,423.7***	216.72***	154.01***	158.47***	213.67**	230.21***	259.05	226.71***	143.84***
Adjusted R-squared	0.3311	0.3302	0.3309	0.3298	0.1642	0.1639	0.1644	0.168	0.1770	0.1773	0.1773	0.1768

Notes: Method: OLS. The variable used to proxy for physical capital is Industry dummy. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.
The number reported are the marginal effects. Significance tests with bootstrapped standard errors in parentheses (Bootstrap replications= 50).

Our results show that the innovations introduced positively affect the productivity of firms. However, surprisingly, the estimated coefficient shows that the effect is not significant for the traditional and KIBS sector. Only Product innovation has a positive and significant effect for traditional services companies. In line with these results, Musolesi and Huiban (2010) also found no impact of non-technological innovations in French knowledge intensive services. Is also important to note that the impact of innovation on productivity may vary over time because innovation has different adjustment cost and also involves different risk. The effect of introducing new product or process might perhaps materialize faster in manufacturing than services. Thus in conclusion more research is needed in this domain. Also to have a strong conclusion is very important to have a dynamic approach using panel data.

Among other controls throughout all specifications, exporting, foreign ownership and skilled workers are highly correlate with a firm productivity. This is an expected result. Exporters tend to have 70 per cent higher productivity in traditional and manufacturing companies. The same relation is 40 per cent for KIBS. This of course do not show the effects of exporting, but may also be due to better firms with higher productivity self-selecting entry into exports market (Helpman et al. 2004).

On the other hand, quantile regressions are reported in table 12. For each innovation outcome the productivity for innovators is statistically significant at the first quantiles. At the very high end of the distribution the effect tends to be non-significant for KIBS and traditional services. In the case of manufacturing companies, the effect tend to be small (but not negligible) over large parts of the distribution. However, it is much larger at the lower end. It suggest that the pattern of the effect is largest at the bottom of the productivity distribution. Also we find that innovation outcomes is not positive throughout the entire distribution. For example, for process innovation outcome for the 25th percentile the estimate effect for traditional services is 34% and 39% for KIBS companies. The results reported, indicate that the innovation effect is not constant over the productivity distribution. We can also reject the equality coefficients hypothesis.

Our model suggest there is a rather large difference in productivity at the bottom of the distribution. The finding that the innovation Premium is positive and significant for product, process and non-technological innovation at the lower percentiles for services companies, is relevant from an economic point of view all over the productivity distribution. It is important because innovation has a positive effect on productivity for low productivity companies. In general, the results suggest that there is a division between innovators and non-innovators companies in productivity. Innovating requires paying substantial fixed cost, implying that firms must increase their productivity to recoup this cost. We should expect this effect to be highest at the lower end of the distribution. This dimension of firm heterogeneity remains undetected if only the estimates for the innovation effect at the conditional mean of the productivity distribution are studied. The difference between the mean estimates and the estimates at the bottom of the productivity distribution are different to an economically meaningful magnitude.

Table 12: Productivity Equation

Traditional Services												
Variables	Product				Process				Non- Technological (Marketing/ Organizational)			
	OLS	Q=0.25	Q=0.50	Q=0.75	OLS	Q=0.25	Q=0.50	Q=0.75	OLS	Q=0.25	Q=0.50	Q=0.75
Predicted Product Innovation Output	0.3257** (0.163)	0.642*** (0.179)	0.266** (0.0906)	0.188 (0.163)	0.1461 (0.160)	0.345*** (0.176)	0.188* (0.112)	0.062 (0.123)	0.0891 (0.138)	0.306** (0.150)	0.1106 (0.099)	0.035 (0.063)
Exports Dummy (t-1)	0.6909*** (0.1574)	0.570*** (0.207)	0.555*** (0.140)	0.844*** (0.199)	0.697*** (0.181)	0.625*** (0.164)	0.584*** (0.112)	0.829*** (0.227)	0.7005*** (0.168)	0.563*** (0.221)	0.590*** (0.124)	0.833*** (0.248)
Foreign Ownership	0.7408*** (0.242)	0.671 (0.446)	0.777*** (0.206)	0.832*** (0.363)	0.708*** (0.230)	0.631 (0.414)	0.728*** (0.239)	0.830*** (0.350)	0.7182*** (0.2425)	0.658* (0.396)	0.731*** (0.304)	0.847*** (0.345)
Skills (t-1)	0.4259*** (0.085)	0.318*** (0.074)	0.350*** (0.095)	0.384*** (0.129)	0.434** (0.078)	0.368*** (0.118)	0.355*** (0.089)	0.405*** (0.105)	0.4331*** (0.0899)	0.328*** (0.115)	0.360*** (0.102)	0.407*** (0.143)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.3311	0.145	0.226	0.282	0.3302	0.1430	0.2260	0.2817	0.3300	0.1428	0.2257	0.2817

KIBS												
Variables	Product				Process				Non- Technological (Marketing/ Organizational)			
	OLS	Q=0.25	Q=0.50	Q=0.75	OLS	Q=0.25	Q=0.50	Q=0.75	OLS	Q=0.25	Q=0.50	Q=0.75
Predicted Product Innovation Output	0.153 (0.205)	0.5173*** (0.186)	0.1189 (0.237)	-0.0662 (0.250)	0.054 (0.187)	0.393*** (0.167)	0.0431 (0.236)	-0.113 (0.235)	0.511*** (0.1249)	0.303* (0.181)	0.023 (0.239)	-0.116 (0.194)
Exports Dummy (t-1)	0.399** (0.196)	0.2773 (0.292)	0.5519*** (0.209)	0.3132 (0.277)	0.407** (0.218)	0.250 (0.221)	0.585*** (0.158)	0.298 (0.276)	0.728*** (0.0864)	0.261 (0.206)	0.597*** (0.221)	0.287 (0.189)
Foreign Ownership	0.487** (0.218)	0.7431*** (0.215)	0.2710 (0.447)	0.563 (0.394)	0.492** (0.217)	0.760*** (0.225)	0.243*** (0.135)	0.539*** (0.103)	0.659*** (0.201)	0.702*** (0.245)	0.283*** (0.135)	0.562*** (0.122)
Skills (t-1)	0.745*** (0.109)	0.6902*** (0.143)	0.5327*** (0.099)	0.973*** (0.149)	0.744*** (0.122)	0.706*** (0.151)	0.533*** (0.102)	0.966*** (0.142)	0.474*** (0.0716)	0.715*** (0.138)	0.534*** (0.073)	0.951*** (0.168)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.1642	0.0692	0.0846	0.1045	0.1642	0.0683	0.0845	0.1047	0.1638	0.0674	0.0844	0.1048

Table 12: (Continued) Productivity Equation

Variables	Manufacturing											
	Product				Process				Non- Technological (Marketing/ Organizational)			
	OLS	Q=0.25	Q=0.50	Q=0.75	OLS	Q=0.25	Q=0.50	Q=0.75	OLS	Q=0.25	Q=0.50	Q=0.75
Predicted Product Innovation Output	0.702***	0.740***	0.822***	0.606***	0.637***	0.673***	0.552***	0.583***	0.608***	0.642***	0.519***	0.567***
	(0.188)	(0.132)	(0.145)	(0.107)	(0.169)	(0.154)	(0.177)	(0.105)	(0.154)	(0.180)	(0.180)	(0.146)
Exports Dummy (t-1)	0.701***	0.581***	0.817***	0.862***	0.734***	0.598***	0.863***	0.875***	0.731***	0.580***	0.885***	0.883***
	(0.108)	(0.109)	(0.108)	(0.087)	(0.092)	(0.118)	(0.106)	(0.095)	(0.099)	(0.135)	(0.100)	(0.082)
Foreign Ownership	0.628***	0.418*	0.382	0.796***	0.684***	0.467*	0.528**	0.907***	0.654***	0.519**	0.486*	0.486***
	(0.204)	(0.237)	(0.306)	(0.305)	(0.191)	(0.279)	(0.264)	(0.267)	(0.187)	(0.278)	(0.279)	(0.279)
Skills (t-1)	0.471***	0.264***	0.328***	0.579***	0.473***	0.268***	0.329***	0.595***	0.482***	0.271**	0.336***	0.336***
	(0.082)	(0.103)	(0.105)	(0.105)	(0.081)	(0.128)	(0.117)	(0.101)	(0.088)	(0.139)	(0.113)	(0.113)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.1770	0.0735	0.1323	0.1656	0.1773	0.0735	0.1309	0.1637	0.1760	0.0712	0.1294	0.1645

Notes: The variable used to proxy for physical capital is Industry dummy. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The number reported are the marginal effects. Significance tests with bootstrapped standard errors (in parentheses). Observations: Traditional services= 1,396; KIBS= 926; Industry= 90. Test of equality coefficients reject the Null hypotheses for all of the estimators.

6.5 Robustness Check

For robustness check we use a new set of innovation outputs using as indicator the following:

- Technological indicator: Dummy: 1 if product or process innovation are equal one. Non
- Non-technological Indicator: Dummy: 1 if marketing and organizational innovations are equal one.

Table A8 (see the appendix) shows the estimation of innovation output for technological and non-technological innovation. Table A9 shows the impact of the predicted innovation outcomes into productivity equation. The results are not quite different as the previous estimations. Thus, the results are not sensitive to specification- when including the dummies for technological and non-technological output.

7. Conclusions and further research

This study has presented first-hand evidence of the patterns of innovation by firms in the manufacturing and service industries. To the best of our knowledge, this is the first such study of innovation in Colombian service firms. Similarly, the use of EDIT data for the manufacturing sector has enabled us to update previously reported findings on innovation patterns. The main results are that Colombian firms do engage in innovation activities regardless of whether they manufacture goods or provide services.

This study analyzed the link between innovation and productivity using the CDM model. In particular, we have investigated how these links differ among different service companies, especially knowledge intensive service (KIBS) and traditional services (less KIBS). Our results show that the widely used CDM model (introduced first in Crepon et al. 1998) adequately describes the innovation process in Colombian service and manufacturing companies. We have found that despite the efficiency of turning innovation investments into innovation outputs and these into performance is higher in manufacturing companies. The service sector, show remarkably low performance in transforming innovation investments into success innovation outputs and these into productivity. The difference can perhaps be explained by the fact that in services is more difficult to appropriate amount of innovation investment due to less information for predicting financial returns.

On the other hand, we believe that mean estimates of the innovation effect on productivity are relatively uninformative as we find substantial heterogeneity throughout the distribution. For that we add a novelty into the CDM model, we employ quantile regressions to estimate the firm performance. Our model suggest there is a rather large difference in productivity at the bottom of the distribution. The finding that the innovation Premium is positive and significant for product, process and non-technological innovation at the lower percentiles for services companies, is relevant from an economic point of view all over the productivity distribution. It is important because innovation has a positive effect on productivity for highly productive companies

Concerning the role of public support for innovation we have found that those firms how have obtained some public support are more likely to take innovation decision but not more likely to invest in innovation activities. If policy makers aim at providing support to the innovation activity, they must take into account that this type of support might not be the best strategy for all firms. However more feasible data (dynamic) is needed to have a strong evidence. This is due to the nature of public support tools have some dynamics over time that we cannot capture in cross sectional data.

On the other hand we have found that openness to external sources of knowledge is an important factor to develop innovations. As such, the variation in openness in innovation could have been expected to be one potential explanation of the varying efficiency of the innovation process in different sectors. However we have found in this paper, this does not seem to be a factor that explains the discrepancy between services and manufacturing firms.

We believe that our results can be useful for policy makers and market practitioners in their attempt to monitor and evaluate innovative activities in the Colombian service sector. This is in turn could contribute to reinforce their competitiveness and their overall economic performance. Finally, a direction for further research is to analyze a set of industries using panel data at the enterprise level. It might deal with potential simultaneity and endogeneity problems. We should note that our results are constrained by these problems.

Appendix

Table A1: Composition of the data set

CIIU Revision 3 A.C.	Activities	Inclusion Parameters	N
	KIBS		954
K	Real estate, renting and business activities	>20 personas	406
I	Transport, storage and communications	>20 personas	354
J	Financial intermediation	CENSO	194
	Traditional Services		1,419
E	Electricity, gas and water supply	>20 personas	118
F	Construction	>20 personas	302
G	Wholesale and retail trade and reparation of equipment	>50 personas; ingresos >COP$5,000	492
H	Hotels and restaurants	>40 personas; ingresos >COP$3,000	185
N	Health and social services	>20 personas; >COP$1,000	189
O	Other community and social and personal services	>20 personas; >COP$1,000	133
D	*Manufacturing Industrial*	>10 personas; >COP$130	905
	TOTAL		3,278

Notes: * Survey of Innovation and technological development EDITS-II Services (2008-2009) and Industry EDIT III (2007-2008), EDIT III; ** Survey of Innovation and technological development Services EDITS-III (2010-2011) and Industry EDIT IV (2009-2010). The parameters of annual revenues are expressed in millions of pesos of 2009.

Table A2: Definitions of the variables used in the regression analysis

Variable Name	Variable Definition	Period of Time
Productivity	Sales per employee (in log)	t, t-1
Relative Productivity	A measure of productivity distance of the firm relative to the mean of its sector. For each sector we compute the average labor productivity as a sales per employee. Each firm labor productivity in t-1 is divided by the average of its sector.	t, t-1
Investment Intensity	Total Innovation expenditures per employee (in log)	t, t-1
Process Innovation	Dummy: 1 if the firm reports having introduced new or significantly improved production processes	t
Product Innovation	Dummy: 1 if the firm reports having introduced new or significantly improved products	t
Marketing Innovation	Dummy: 1 if firm reports having introduced marketing innovation	t
Organizational innovation	Dummy: 1 if firm reports having introduced organizational innovation	t
Foreign ownership	Dummy: 1 if foreign owners have 40% of the ownership in the firm.	t
Export Dummy	Dummy: 1 if firm has positive exports.	t, t-1
Engagement in R&D activities	Dummy variables which takes the value 1 if the firm engaged in R&D activities.	t
Stable R&D	Dummy: 1 if firm reported being continuously engaged in R&D activities	t
Public Support	Dummy: 1 if the firm received local or regional funding for innovation projects	t
Innovation Barriers (% firms)		
Financing Constraints		
All	Dummy: 1 if firm considered all barrier to be of high importance to innovation	t
Internal	Dummy: 1 if firm considered internal barrier to be of high importance to innovation	t
External	Dummy: 1 if firm considered external barrier to be of high importance to innovation	t
Market risk	Dummy: 1 if firm considered market uncertainty barrier to be of high importance to innovation	t
Lack of Regulations or standard	Dummy: 1 if firm considered regulation as barrier to be of high importance to innovation	
Formal Protection	Dummy: 1 if firm uses registration of design patterns, trademarks or copyright to protect inventions or innovations	t
Sources of information		
Suppliers as source of information	Dummy: 1 if information from suppliers were of high importance	t
Customers as source of information	Dummy: 1 if information from customers were of high importance	t
Institutions as source of information	Dummy: 1 if information from universities or other higher education, government or private nonprofit institutes were of high importance	t
Skills	Dummy: 1 if Professionals and Technicians as a Percentage of total employee is higher than 40%	t, t-1
Skills Low	Dummy: 1 if firm has no employees with higher education degree.	t, t-1
Skills Medium	Dummy: 1 if firm has a positive share of employees with higher education but below 40%.	t, t-1
Skills High	Dummy: 1 if firm has more than 40% of employees with higher education	t, t-1
Firm size	Natural log of the number of employees	t, t-1

Industry dummies	Four dummy variables are defined in three groups according with CIIU classification (one digit). Services, Industry, KIBS	t

Table A3: Summary of Explanatory Variables

Stage	Equation	Explanatory Variables
First	Public Support	*Pr(Public Support)= Φ(Finance constrain, lack regulation, relative productivity(t-1), stable R&D, formal protection, foreign ownership, exports dummy (t-1), size, , sectoral dummies).*
Second	Innovation Decision (Selection Equation)	*Pr(Innovation Decision)= Φ(innovation intensity(t-1), Public support (predicted), formal protection, market market risk, lack personnel, foreign ownership, exports dummy (t-1), relative productivity(t-1), skills(medium, high), size, sectoral dummies).*
	Innovation Intensity	*Log(Innovation Intensity)= f(innovation intensity(t-1), Public support (predicted), source of knowledge (Suppliers, Customers, Institutional), foreign ownership, exports dummy (t-1), skills(medium, high), size, sectoral dummies)*
Third	Innovation Production (Product, Process, Marketing, Organizational)	*Pr(Innovation Output)= Φ(Predicted Log-innovation intensity, Public support (predicted), formal protection, source of knowledge (Suppliers, Customers, Institutional), skills(medium, high), foreign ownership, exports dummy (t-1), size, sectoral dummies)*
Fourth	Productivity Equation	*Log(Labour Productivity)=f(predicted innovation outcomes, skills, foreign ownership, exports dummy (t-1), firm size, 1-digit industry dummies)*

Table A4: Correlation Matrix: Barriers for innovation (whole sample)

	All	Internal	External	Market risk	Lack of information and internal capabilities	Regulations or standards as barrier
All	1.00					
Internal	1.00	1.00				
External	1.00	0.80	1.00			
Market risk	0.44	0.44	0.45	1.00		
Lack of information and internal capabilities	0.40	0.41	0.49	0.58	1.00	
Regulations or standards as barrier	0.35	0.31	0.35	0.50	0.39	1.00

Note: Correlations were calculated using the Tetrachoric method

Table A5: Correlation Matrix: Source of Knowledge variables (whole sample)

	Internal source within enterprise	Internal source within the group	Suppliers as source of informati on	Customers as source of information	Universities as source of information	Government as source of information	Protect innovations
Internal source within enterprise	1.00						
Internal source within the group	0.21	1.00					
Suppliers as source of information	0.24	0.33	1.00				
Customers as source of information	0.30	0.52	0.41	1.00			
Universities as source of information	0.17	0.21	0.27	0.25	1.00		
Government as source of information	0.09	0.35	0.19	0.25	0.69	1.00	
Protect innovations	0.24	0.02	0.00	0.17	0.15	0.19	1.00

Note: Correlations were calculated using the Tetrachoric method.

Table A6: Correlation Matrix: Innovation output Variables (whole sample)

	Product Innovation	Process	Marketing	Organizational	Internal Research and Development
Product	1.00				
Process	0.81	1.00			
Marketing	0.73	0.73	1.00		
Organizational	0.75	0.81	0.77	1.00	

Note: Correlations were calculated using the Tetrachoric method.

Table A7: Correlation Matrix: Explanatory variables for productivity Equation (Whole sample)

	Exports (t-1)	Foreign ownership	Size
Exports (t-1)	1.00		
Foreign ownership	0.1479	1.00	
Size	0.2138	0.1325	1.00
Skills (lag)	-0.058	0.0295	-0.1160

Note: Correlations for dummy variables were calculated using the Tetrachoric method.

Table A8: Robustness Check**:** Innovation production function (Technological and Non-Technological innovation)

VARIABLES	Technological= Product and process			Non-Technological: Marketing and Organizational		
	Traditional (1)	KIBS (2)	Industry (3)	Traditional (4)	KIBS (5)	Industry (6)
Innovation Intensity (Expenditure per employee) (Predicted)	0.0546*** (0.00491)	0.0462*** (0.00644)	0.0998*** (0.0074)	0.0406*** (0.0052)	0.0374*** (0.0071)	0.0667*** (0.0089)
External as source of information	0.2367 *** (0.0177)	0.219*** (0.0234)	0.1900*** (0.0237)	0.269*** (0.0161)	0.2341*** (0.0238)	0.2183*** (0.0259)
Institutions as source of information	0.0635** (0.0310)	0.0636 (0.0421)	0.0395 (0.0417)	0.1248*** (0.0308)	0.0929** (0.0424)	0.0711* (0.0396)
Exports Dummy (t-1)	-0.0305 (0.0312)	0.0167 (0.0415)	0.0663*** (0.0252)	-0.0143 (0.0296)	-0.0249 (0.0473)	0.0199 (0.0269)
Foreign Ownership	-0.078 (0.0570)	-0.0279 (0.0782)	-0.0325 (0.0404)	-0.0671 (0.0596)	-0.198 (0.322)	-0.0182 (0.0561)
Formal Protection	0.0704 (0.0544)	-0.0140 (0.0756)	0.0648 (0.0508)	0.0333 (0.0521)	-0.0303 (0.0726)	0.1620*** (0.0462)
Skills (t-1)	-0.0334* (0.0196)	-0.0243 (0.0217)	-0.0346 (0.0246)	-0.0082 (0.0185)	-0.0284 (0.0213)	0.00268 (0.0256)
Size	0.0278*** (0.00448)	0.0247*** (0.0048)	0.0060 (0.0075)	0.0286*** (0.0044)	0.0218*** (0.0047)	0.0115 (0.0080)
IDI= Innovation=0 & R&D=1 (Note)	0.0299 (0.0548)	0.0652 (0.0537)	-0.2729 (0.0437)	-0.0447 (0.005)	0.1160** (0.0565)	-0.0442 (0.0089)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,419	926	905	1,419	926	905
Wald c2	460.85***	270.64***	275.39***	390.73***	283.69***	305.11***
Log pseudo likelihood	-513.516	-298.316	-286.069	-467.53	-306.238	-327.753
Pseudo R2	0.3824	0.4301	0.4868	0.3933	0.4062	0.3843

Notes: Each column shows estimated average marginal effect. Method: Probit. *Significant at 10%, **significant at 5%, ***significant at 1%. The number reported are the marginal effects, and the corresponding standard errors in parenthesis. Significance tests with bootstrapped standard errors (Bootstrap replications= 50). IDI= Innovation variable for those firms without innovation activities but with positive R&D report.

Table A9: Robustness Check**:** Productivity Equation controlling for technological and non-technological output

Variables /Sector	Traditional Services		KIBS		Manufacturing	
	Technological	Non-Tech	Technological	Non-Tech	Technological	Non-Tech
Predicted Innovation Output	0.1546	0.0891	0.0236	0.0352	0.5293***	0.6079***
	(0.118)	(0.138)	(0.143)	(0.164)	(0.135)	(0.154)
Exports Dummy (t-1)	0.6990***	0.7005***	0.4093**	0.4101**	0.7249***	0.7312***
	(0.146)	(0.168)	(0.224)	(0.213)	(0.093)	(0.099)
Foreign Ownership	0.7135***	0.7182***	0.4951***	0.4832***	0.6585***	0.6547***
	(0.237)	(0.2425)	(0.202)	(0.187)	(0.159)	(0.187)
Skills (t-1)	0.4321***	0.4331***	0.742***	0.7444***	0.469***	0.4823***
	(0.0927)	(0.0899)	(0.119)	(0.102)	(0.095)	(0.088)
Industry fixed effects (1 digit)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,396	1,396	926	926	902	902
Wald chi2	813.06	869.91***	164.70***	175.16***	181.41***	267.80***
Adjusted R-squared	0.3304	0.3300	0.1638	0.1686	0.1760	0.1760

Notes: Robust standard error in parentheses. Method: OLS. The variable used to proxy for physical capital is Industry dummy. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The number reported are the marginal effects. Significance tests with bootstrapped standard errors (Bootstrap replications= 50)

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