Innovation, R&D Investment and Productivity in Colombia[1]

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Abstract

The main objective of this paper is to establish a formal relationship between innovation and performance using Colombian firm-level data. We find that, as predicted by the literature, the production of goods and services new to the firm and to the domestic market enhances firms' productivity and sales. In the same way, innovation in management and marketing boosts firms' productivity and sales. However, contrary to theoretical predictions, the production of goods and services new to the international market has a strong negative impact on TFP, although it largely increases sales when firms invest in R&D. We also study the factors behind the firms' decision to invest in innovation, the intensity of such investment and the returns to investment in innovation.

JEL Classification: C21; C31; C34; C35; L60; O31; O32; O14; O47

Keywords: Innovation; Productivity; Economic Performance; Total Factor Productivity; Generalized Tobit model; Firm-level data; Colombia

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1 Introduction

Innovation is considered a major driver of competitiveness and economic growth. There is extensive research linking innovation and productivity that finds strong evidence of innovation and R&D being the engines for productivity growth. However, the evidence is weak when establishing this relationship outside the developed world. Masso and Vaher (2008) looked at the link of innovation and productivity using Estonian firm-level data and found that, depending on the macroeconomic conditions, product and process innovation had a positive effect in productivity. On the other hand, Benavente (2006) does not find evidence of R&D expenditure and innovative results having an impact on productivity based on Chilean firms' data.

The literature on innovation in Colombia is quite scarce and this paper constitutes the first study formally exploring the link between innovation and productivity. Alvarado (2000) uses the 1996 round of the Colombian innovation survey (EDIT) with 885 industrial firms to study their innovative behavior. Specifically, the author estimates the decision of firms to invest in R&D and the intensity of that investment. He finds that the firm size is positively correlated with the decision to invest but negatively correlated with the innovation intensity. The author explains his results based on the fact that larger firms have advantages inherent to their size that makes them more likely to invest in R&D. In contrast, smaller firms tend to invest greater amounts than larger firms due to their greater relative need of increasing their equipment for innovation. Alvarado also finds that firms that receive foreign investment, that have higher organizational capacity and access to international markets are more likely to invest in R&D and their investment intensity is higher. Finally, he shows that firms in the plastic and chemical industries are more likely to invest in R&D and with higher intensity.

In recent years Langebaek and Vasquez (2007) use data from the 2005 round of the EDIT and estimate a Tobit model to analyze the determinants of innovation in the Colombian manufacturing industry. The authors conclude that the innovation activity is highly related to firm size, the presence of foreign capital and the level of human capital of the firm.

The main contributions of this paper are threefold: first, it adds to the literature on innovation and productivity in developing economies and constitutes the first study of this nature using Colombian firm-level data. Moreover, we employ data on manufacturing from two merged surveys which collect innovation information (EDIT) and other relevant firm-level data (EAM) to estimate a more accurate measure of firm's performance such as total factor productivity.

Second, we take advantage of the availability of a relatively long panel of firms which allow us to study the effects of innovation investment not only on current levels of productivity but also on the firm's performance in the following three years. By doing this, we explore the possibility of innovation having lagged effects on productivity and also attempt to model more explicitly the endogeneous nature of the model. Unfortunately, the innovation dataset is only available for one year[2], so that we cannot pursue a more dynamic-type of analysis.

The third main contribution of our research is that, thanks to the richness of the data employed, we are able to measure the effect of different variables thought to be relevant for making innovation investment decisions. For instance, we estimate the impact of innovation policies, sources of innovation ideas and formal protection. Also, we explore the effect of firms' characteristics such as export share, size of foreign capital, capital intensity, and human capital composition, among others. Furthermore, we study the effects on productivity of different types and levels of innovation outputs (adaptation and innovation of goods and services, new production processes, and new management and marketing procedures).

The remainder of the paper is distributed as follows. Section 2 summarizes the evolution of the Science Technology and Innovation policy in Colombia. Section 3 briefly describes the evolution of the manufacturing sector in the last eight years. Section 4 presents the theoretical model and the estimation strategy. Section 5 describes the datasets and a brief descriptive analysis of the main variables. Section 6 presents the empirical results and Section 7 concludes.

2 Science, Technology and Innovation Policy in Colombia

The innovation policy in Colombia was embedded within the science and technology policy until 1995 when the National Innovation System was created and more specific and focused actions in this area were undertaken. Hence, in order to understand the evolution of the innovation policy in Colombia it is important to review the science, technology and innovation (STI) policy as a

[2] For some variables the information is collected separately for 2003 and 2004.

whole. The development of the STI policy in Colombia can be divided into four stages: the first starting in 1968[3] until 1989, the second from 1990 until 1999, the third from 2000 until 2008 and a new current stage starting this year. In what follows, we briefly describe each of the stages, emphasizing on the last two.

The beginning of the first stage of the Colombian STI policy was marked by the creation of Colciencias and the National Council of Science and Technology (CNCT) in 1968. Colciencias, originally attached to the Ministry of National Education, was the institute in charge of financing, coordinating, promoting and implementing all programs and projects related to technological and scientific development. During this period the first graduate programs, including doctorate programs, were created; institutes dedicated to R&D were founded - some of which are still functioning[4]-.and the IDB Loan 1: ICFES-Colciencias was disbursed, which became the main instrument to modernize research systems and the provision of technological services to the productive sector. Nevertheless, during this period the emerging institutions were not articulated and their actions and objectives did not follow a defined and cohered policy. In 1988, the Mission for Science and Technology was organized aimed at making a diagnostic and proposing a new regulatory and institutional framework for the development of science and technology in Colombia.

The second stage started with the enactment of the Law 29 of 1990 which, based in the results from the Mission, defined the national policy of science and technology. In the same year, Colciencias was attached to the National Planning Department (Decree 585) with the intention of linking together the planning of economic and science and technology development. Also, through Decree 1767 of 1990 the National System of Science and Technology (SNCT) was created, with the participation of the government (at the central and regional levels), the private

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[3] Some authors consider the first stage to the period prior to 1968, starting in the colonial times, which include the foundation of the first schools and universities, the Botanical Expedition, and the creation of centers providing technological services to the emerging industrial sector. However, there was not an institutional structure dedicated to planning, directing, or promoting STI activities. See Garay (1998).

[4] Instituto de Inmunología, Instituto Colombiano de Pertróleo, Instituto Colombiano de Hidrología, Metrología y Adecuación de Tierras, y el Instituto Nacional de los Recursos Naturales Renovables y del Ambiente, La Empresa Colombiana de Productos Veterinarios, el Centro de Investigaciones Biológicas, el Centro Internacional de Investigaciones Médicas, el Laboratorio de Investigaciones sobre la Química del Café, el Centro de Investigaciones de la Caña de Azúcar, el Centro Internacional de Agricultura Tropical y la Fundación para la Educación Superior y el Desarrollo. (Garay , 1998)

sector and the academia. The SNCT was headed by the CNCT, the councils for national programs, and the regional commissions of science and technology while Colciencias acted as Technical and Administrative Secretary of the councils for national programs.

Late in 1994, Colciencias underwent a major restructuring in which two separate and independent units were created: the Strategic Programs Subdivision and the Innovation Subdivision in charge of all programs, projects and activities related to the productive sector. Such restructuring reflected recognition of the importance of both the participation of the productive sector as well as innovation activities per se. Following this trend, in 1995 the National Innovation System (SNI) and the Regional Innovation Systems were developed with the purpose of increasing productivity and competitiveness by implementing a new business development strategy based on the generation of new products and processes, technological adaptation, advanced job training and a renovated corporate culture. New and diverse actors and institutions became part of the SNI, such as the companies and their associations, SENA, Superintendence of Industry and Commerce, centers for technological development, incubators of technology-based businesses, regional productivity centers, Bancoldex, Proexport, IFI, *Fondo Nacional de Garantías* and the banking sector among others (Conpes 3080).

In addition, in terms of policy and legislation, other important steps were taken: the enactment of the Law 6 of 1992 giving tax incentives related to STA, and of the Law 344 of 1996 ordering SENA to allocate 20% of its income from payroll taxes on private employees to the development of programs for competitiveness and productive technological development[5], and the approval of the first Conpes on ST (2739 of 1994) defining the national policy for 1994-1996. Also, two new IDB loans for projects administered by Colciencias were approved and disbursed (II-Colciencias 1990 and III-Colciencias 1994-1998). Finally, the Colombian Observatory of Science and Technology was created in 1999.

The third stage represents the beginning of the consolidation of the policy of STI. In 2000, the Conpes document 3080 defined the national policy of science and technology for 2000 and 2002 and the Conpes document 3179 of 2002 gave support to doctoral education in

[5] SENA runs these programs through its centers for vocational training or through agreements with other institutions and technological development centers.

Colombia. In terms of medium and long term policy, STI has been given a key role in the last two National Development Plans (PNDs). Specifically, new resources were assigned for STIA in the 2002-2006 PND (Law 812 of 2003) and in the 2006-2010 PND STI is established as one of its main dimensions, and the government goes beyond recognizing the importance of knowledge and innovation for economic and social development and defines specific objectives and actions, including the need of institutional and legal changes and the commitment of investing more in this sector[6]. Other government documents setting out the STI medium and long term policy guidelines are *Visión 2019: Fundamentar el crecimiento y el desarrollo social en la ciencia, la tecnología y la innovación* (DNP, 2006) and *Colombia Construye y Siembra Futuro* (Colciencias, 2008).

During this period, the public resources directed to STI investment have increased considerably. For example, the Law 812 of 2003 dictated that SENA should allocate one fourth of the 20% of ITD-oriented resources to subscribing agreements with Colciencias for the promotion of science, technology and innovation activities[7]. In Figure 1 we present SENA's investment in ITD since 2003. Likewise, in the last two years, Colciencias budget was increased by 46 and 59% in real terms respectively as shown in Figure 2. These new resources should be directed to finance three main action lines: STI research projects, doctoral studies (national and abroad) and technical development and innovation projects for the productive sector.

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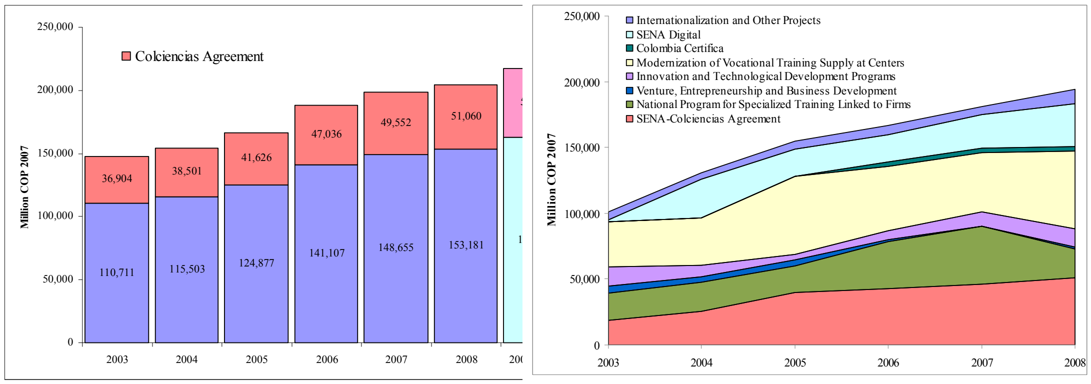
[6] The 2006-2010 PND sets the strengthening of the STI sector as a key tool for improving employment, security, poverty and health problems and established eight programmatic strategies: i) increase knowledge generation; ii) promote innovation and productive development; iii) promote social STI appropriation; iv) increase and strengthen human capabilities for STI; v) reinforce SNCTI's institutionality; vi) reinforce the infrastructure and information systems for STI; vii) promote regional integration; and viii) strengthen STI's international projection.

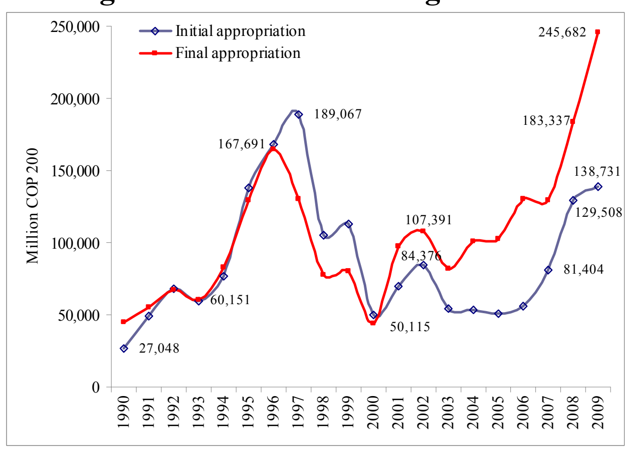
[7] Since 2002, SENA has financed 7,592 projects worth $991,415 pesos under its umbrella of innovation and technological development (ITD) programs. Among these, it merits mentioning the *Innovación y Desarrollo Tecnológico con el Medio Externo a la Entidad* (ITD with the Environment External to the Firm) whose main objective is to strengthen the technological capacity of firms. The program finances projects presented by firms which should lie on one of three program lines: i) development and implementation of hard technologies; ii) transferring and appropriation of (soft) technologies for increasing productivity; and iii) development and implementation of good practices in the agro-industrial chain. The program has financed 2,856 projects worth $61,879 pesos in the period 2002-2008. Also, SENA administers the government Fund *Fondo Emprender*, which finances entrepreneurial projects developed by apprentices, university students in senior year or by young professionals with at most two years of experience. The beneficiaries receive nun-refundable seed capital for their projects provided these are applications of their studies. Currently, 1657. projects worth $94.711 million pesos have been approved through 6 national and 40 regional calls. Additionally, SENA leads the *Red de TecnoParques* program, a network of technoparks, financed by the public and private sector. The objective of this program is to promote among the public interest for innovation leading to the formation of new enterprises and also to provide advisory services on the application of new technologies and technological solutions to firms.

Figure 1: SENA's Role on Innovation and Technological Development (ITD)
Panel A. Budget Allocation for ITD **Panel B. ITD related Programs**



Notes: i) Colciencias' Agreements account for one fourth of the 20% of payroll tax contributions received by SENA allocated to innovation and technological development. ii) The 2009 value corresponds to the SENA's projection deflated using the 2009 inflation target.
Source: Author's calculations based on SENA reports.

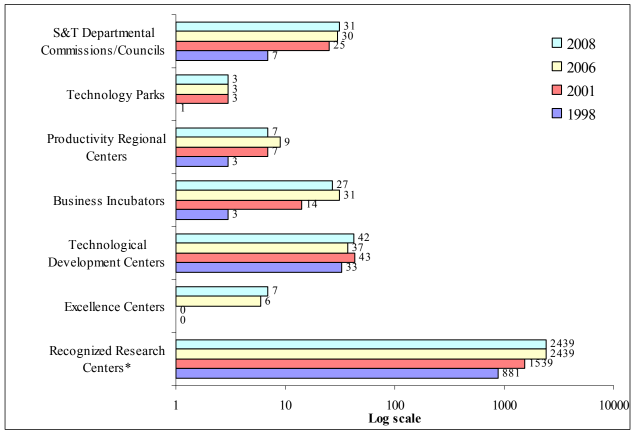
Figure 2: Colciencias Budget



Notes: i) The 2009 budget corresponds to estimations based on MGMP (Medium Term Expenditure Framework). ii) November's CPI was used for 2008. iii) 2009 inflation target was used for 2009.
Source: Colciencias, DANE (CPI). Calculations by DNP.

Also, the number of STI supporting institutions has increased significantly in the last ten years. Up to 2008, following a process based on the promotion and preservation of quality, Colciencias has named 2439 recognized research centers, 1558 more than in 1998. Since 2006, 7 Excellence Centers have been created with the commitment of working in continuous contact with international research groups, promoting education at the master and doctorate levels, transferring their knowledge to the productive sector, publishing their work in recognized international journals and being involved in the patenting processes. Other institutions dedicated to the development of STI activities are the centers for technological development, departmental science and technology councils, business incubators, productivity regional centers and technological parks (Figure 3).

Figure 3: STI Supporting Institutions



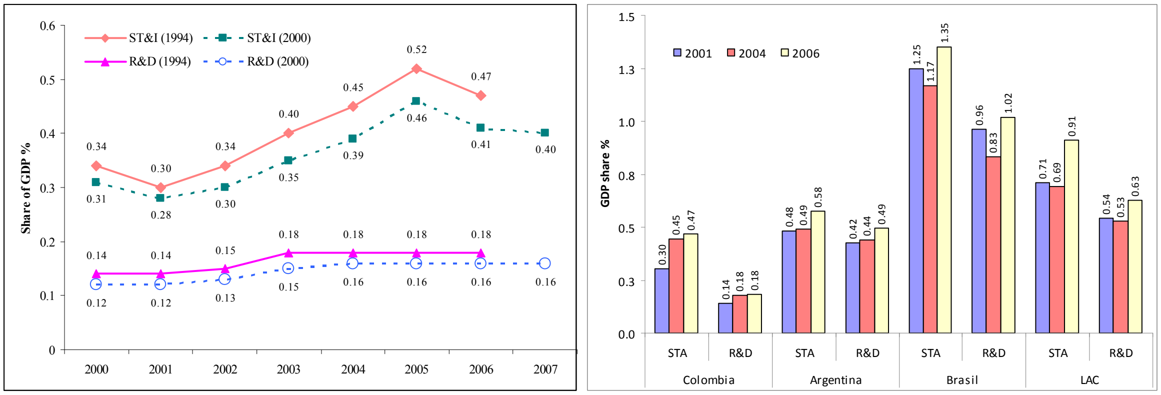
*Since 2002 research centers are categorized between registered and recognized; the latter having concrete results and being voluntarily submitted to a Colciencias classification.
Source: Colciencias

Furthermore, in 2004 the CONPES document 3297 gave way to a process of constructing a national competitiveness strategy that required the participation of all relevant actors at the regional, sectoral and national level. This process, headed by DNP, is known as *Agenda Interna para la Productividad y la Competitividad*. Within the same national strategy, the MCIT's flagship program is oriented to the knowledge economy. The Ministry of Industry and Commerce is implementing new programs towards the achievement of higher and sustained long run growth based on the new knowledge economy: *Más y Mejor de lo Bueno* and *Impulso al Desarrollo de Sectores Nuevos y Emergentes de Clase Mundial*. These programs aim at transforming the Colombian productive structure by promoting the use of knowledge and innovation for developing existent and emerging sectors.

Nevertheless, investment in technology and innovation in Colombia is still low, even though it has increased considerably since 2000. In 2001 spending in STIA and R&D was 0.28% and 0.12% percent of GDP respectively. In 2007, these shares increased to 0.40% for STIA and 0.16% for R&D as shown in Panel A of Figure 4. Comparing to other countries in the region, these shares are around one-fifth to one-half what other neighboring countries like Brazil invest as can be observed in Panel B of Figure 4.

Figure 4: Size of Science, Technology and R&D Activities

Panel A **Panel B**



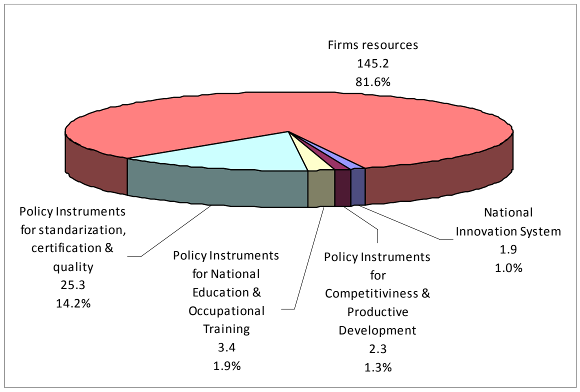
Source: OCyT

Source: RICYT

Moreover, according to EDIT II, the SNI accounts for only 1% (1.9 Billion pesos) of the pool of financing instruments used by firms[8]. Likewise, policy instruments for competitiveness and productive development account for 1.3% (2.3 Billion pesos), instruments for occupational training account for 1.9% (3.4 Billion pesos) and instruments for standardization, certification and quality account for 14.2 % (25.3 Billion pesos). In fact, manufacturing firms finance 82% of their innovation-related activities using their own resources as it is shown in Figure 5.

[8] Policy instruments for innovation and technological development can be divided into direct and indirect. The direct instruments include: co-financing lines and financing lines such as rediscount lines of credit and technological innovation incentives; access to guarantees; tax benefits; and the Colombian Business Award for Technological Innovation Achievement. Within the indirect instruments are all the benefits and services provided by Colciencias, SENA and other SNI actors. For a more complete description of the STI policy instruments see Salazar (2007).

Figure 5: Instruments for Innovation Employed by Manufacturing Firms in 2004
COP Billions



Source: Authors' calculations based on EDIT II

The low public investment in STIA tied the fact that the manufacturing sector barely uses the public instruments available for promoting and financing innovation-related activities, which may be a reflection of institutional weak STIA policy, leads to low expectations in terms of innovation output and its effect on productivity. With this is mind, the government has been recently taking new stronger steps towards the actual inclusion of STI in the national economic development policy at all levels. Specifically, the enactment of Law 1286 of 2009, the new Law of science and technology, strengthens the sector's institutional landscape by giving Colciencias institutional autonomy, creating the National System for Science, Technology and Innovation (SNCTI) and the National Fund for the Financing of STI (Fondo Nacional de Financiamiento a la Ciencia, la Tecnología y la Innovación, FONACyTI) among other related actions. Hence, one may claim that 2009, collecting past efforts, marks the beginning of a new more consolidated stage in the Colombian STI policy with higher expectations for productivity and competitiveness gains.

3 Evolution of the manufacturing sector

In this section we describe some general trends of the Colombian manufacturing sector during the last eight years, based on the Annual Manufacturing Survey (EAM), the database that we used to estimate the model.

In general terms, the manufacturing sector was strongly hit by the crisis of the end of the nineties (in 1999 the Colombian economy dropped by 4.5%), and started a continuous recovering in 2000 (Table 1). Indeed, the industrial production declined around 6% in real terms in 1999, but grew 10% in 2000 and increased from then on. It exhibited an average real growth rate of 7% during the period 2000-2006, and reached a peak of 14% in 2006. Sales also boosted by 9% during the period, after having fallen 9.4% in 1999. Employment in manufacturing followed the same pattern over the analyzed period, but the recovery has been slower than that of sales, recording an average growth rate of 2% in 2000-2006.

Table 1: Manufacturing Sector´s Main Statistics

Million of 2004 constant COP

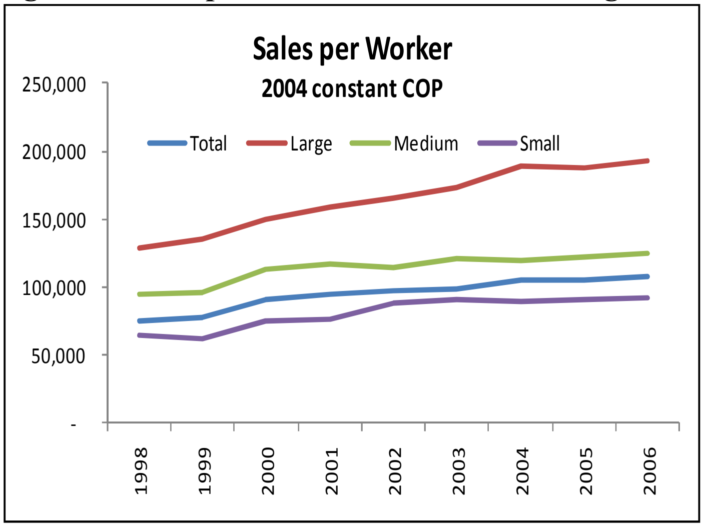
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Number of establishments	**7861**	**7441**	**7246.0**	**6960**	**6881**	**7230**	**7249**	**7524**	**7369**
Growth (%)		-5.3	-2.6	-3.9	-1.1	5.1	0.3	3.8	-2.1
Number of workers	**592,956**	**533,340**	**534,573**	**528,022**	**531,213**	**545,897**	**570,855**	**587,630**	**612,080**
Growth (%)		-10.1	0.2	-1.2	0.6	2.8	4.6	2.9	4.2
Value Added	**33,401**	**31,464**	**34,605**	**35,468**	**36,801**	**39,122**	**42,656**	**44,360**	**50,602**
Growth (%)		-5.8	10.0	2.5	3.8	6.3	9.0	4.0	14.1
Sales	**52,662**	**47,694**	**56,692**	**59,164**	**61,517**	**66,208**	**74,261**	**77,848**	**86,707**
Growth (%)		-9.4	18.9	4.4	4.0	7.6	12.2	4.8	11.4
Exports			**8,526**	**9,863**	**10,321**	**11,370**	**10,507**	**10,695**	**12,457**
Growth (%)				15.7	4.6	10.2	-7.6	1.8	16.5
Exports/GDP			**10.8**	**12.0**	**12.3**	**12.3**	**10.5**	**10.4**	**10.8**

Source: EAM, DANE and authors' calculations

As a consequence, the sector registered an increasing trend in sales per worker, which grew by 5% in average in 2000 - 2006. Figure 6 also shows that labor productivity is positively related to the size of the firm, and it has increased particularly in the case of large firms. Moreover, the gap between these firms and medium and small firms widened during the present decade.

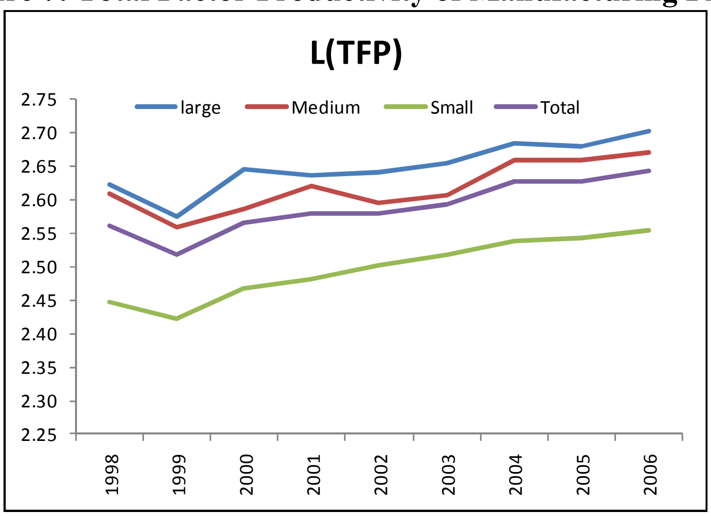
The evolution of total factor productivity (the average of firms´ TFP) has exhibited the same increasing pace and records similar patterns regarding firms' size (Figure 7). Large firms have a TFP greater than that of medium and small firms. The three groups show a drop in 1999 and a recovery from 2000 onwards, although very slowly (the increase in TFP was in average less that 1% during the period 2000-2006), which can be explained by weak innovation activities undertaken by firms.

Figure 6: Sales per Worker of Manufacturing Firms



Source: EAM, DANE and authors' calculations

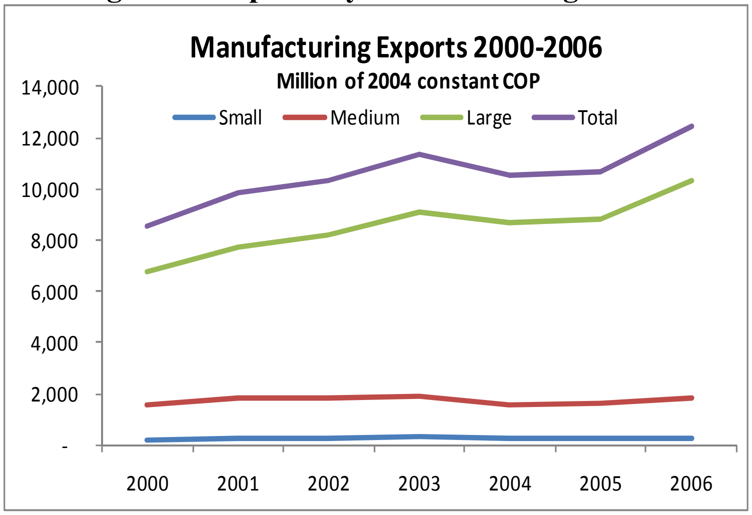
Figure 7: Total Factor Productivity of Manufacturing Firms



Source: EAM, DANE and authors' calculations

The manufacturing sector is not highly exporting, and exports represent only around 11% of the industrial production. The share of exports increased slightly in 2001-2003 (recorded around 12.5%), but was reduced to 10% onwards. However, exports grew during 2000 – 2006 (in average around 7%) especially in large firms, which can be positively related to the TFP growth during the same period (Figure 8).

Figure 8: Exports by Manufacturing Firms



Source: EAM, DANE and authors' calculations

4 The model

The microeconomic analysis linking innovation and productivity follows a structural model first introduced by Pakes and Griliches (1984) and improved by Crépon et al (1998) known in the literature as the CDM model[9]. The CDM model has been the base of recent research on the topic, and has been widely used and extended by several authors (see Annex 1 at the end of the document for a brief survey).

Following Lööf and Heshmati (2006) and Masso and Vahter (2008), we will estimate an extended CDM model specified by the following system of equations:

$$g_i = \begin{cases} 1 & if \quad g_i^* = X_i^0 \mathrm{B}^0 + \varepsilon_i^0 > 0 \\ 0 & if \quad g_i^* = X_i^0 \mathrm{B}^0 + \varepsilon_i^0 = 0 \end{cases} \qquad (1)$$

$$k_i^* = X_i^1 \mathrm{B}^1 + \varepsilon_i^1 \qquad if \quad g_i^* > 0 \qquad (2)$$

$$t_i = \beta^k k_i^* + \beta^q q_{i,-\tau} + X_i^2 \mathrm{B}^2 + \varepsilon_i^2 \qquad (3)$$

$$q_{i,+\tau} = \beta^t t_i + X_i^3 \mathrm{B}^3 + \varepsilon_i^3 \qquad (4)$$

[9] Crépon et al. (1998) included a third equation intended to correct for selectivity and simultaneity issues present in the Pakes and Griliches (1984) model.

The first equation of the system, Eq. (1), describes the decision by firms to invest in innovative activities. The inclusion of this equation is intended to correct for selection of firms into innovation investment. g_i equals one when the firm is engaged in innovation activities, that is, when the latent innovation decision variable, g_i^*, is greater than a threshold, say zero. The second equation of the system, Eq. (2), describes the innovation intensity of the firm, that is, the level of innovation input, given by the latent variable k_i^*. In our empirical analysis this variable corresponds to total investment in innovation activities[10]. Earlier research had focused the analysis on R&D activities; thus we present results restricting investment accordingly. We refer to Model I when considering the broader notion of innovation investment and to Model II when considering R&D as the only innovation input.

The third equation of the system, Eq. (3), corresponds to the innovation output equation also known in the literature as the knowledge equation. Innovation output, t_i, has been generally estimated as the number of patents applied (Crépon et al, 1998) and as a the relative measure of innovative sales (van Leeuwen and Klomp, 2006; Lööf and Heshmati, 2006; Jefferson et al., 2006, among others). Also, some authors have used indicators of product and process innovation (Masso and Vahter, 2008). In our analysis, we use a set of dichotomous variables indicating whether the firm has obtained innovative results. From our database we can classify innovative results into five types: adaptation and innovation of good and services, new production processes, and new management and marketing procedures. We have defined adaptation of goods and services when their production is new to the firm or to the national market while innovation of goods and services when production is new to the international market.

Finally, equation (4) completes the system and corresponds to the productivity or performance equation. In the literature, q_i has been generally measured as value added per employee, or as sales per employee (for instance, Griffith et al., 2005; Masso and Vahter 2008; and Lööf and Heshmati 2006). However, some authors have used measures of total factor productivity -TFP- (Douguet, 2006, and Jefferson et al. 2006). In this present paper, we explore the effect of innovation output on two different measures of firm performance: log of sales per

[10] We define the dependent variable as total investment in innovation per employee. Hence, we do not include size in the set of explanatory variables as we do in the other three equations.

employee and total factor productivity –TFP- (levels and growth rates). For the latter, we follow Levinhson and Petrin (2003) and Olley and Pakes (1996) and estimate the following equation:

$$\ln(TFP_{it}) = \ln(Y_{it}) - \hat{\alpha}\ln(K_{it}) - \hat{\beta}\ln(L_{it}) - \hat{\gamma}\ln(E_{it}) \qquad (5)$$

where Y_{it} denotes gross output, K_{it} denotes capital stock, L_{it} denotes number of workers, and E_{it} denotes energy used for production. This methodology allows us to solve the problem of bias of the coefficients $\hat{\alpha}$ $\hat{\beta}$ and $\hat{\gamma}$ when estimated using other methods such as simple OLS or fixed effects, which can result in overestimated TFP changes[11]

In the system above, $X_i^0, X_i^1, X_i^2, X_i^3$ represent matrices of explanatory variables as shown in Table 2 below. We have chosen this set of variables after reviewing the international literature on innovation and productivity summarized in a table the Annex 1 at the end of this document, and $\mathrm{B}^0, \mathrm{B}^1, \mathrm{B}^2, \mathrm{B}^3$ are the vectors of the corresponding parameters to be estimated. $\varepsilon_i^0, \varepsilon_i^1, \varepsilon_i^2, \varepsilon_i^3$ correspond to the normally distributed error terms in each of the equations with mean zero and constant variance. It is assumed that ε_i^0 and ε_i^1 are jointly normally distributed and correlated with each other, although we test for this explicitly in our empirical section.

In order to identify the effect of innovation in future levels of productivity we estimated equation (4) for productivity levels in 2005 and 2006, in addition to estimating it for productivity levels in 2004. By doing so we aim at testing the hypothesis of innovation having lagged effects on productivity[12] and attempt to model more explicitly the endogenous nature of the model.

[11] Bias and inconsistency in coefficients are driven by the fact that, through OLS, the TFP may be correlated with the quantity of inputs used in the production process.
[12] Masso and Vahter (2008) estimate this effect.

Table 2: Vectors of Explanatory Variables

Equation		Explanatory variables
Eq. (1)	=	(firm's capital stock, human capital indicators (skilled engineers and managers), foreign capital ownership indicator, market share, innovation policy indicators, formal protection indicators, international competition indicator, firm's size indicators, firm's age, firm's age squared, industry dummies)
Eq. (2)	=	(firm's capital stock, human capital indicators (skilled engineers and managers), foreign capital ownership, market share, innovation policy indicators, formal protection indicators, sources of innovation indicators, international competition indicator, sources of financing innovation firm's age, firm's age squared, industry dummies)
Eq. (3)	=	(firm's capital stock, human capital indicators (skilled engineers and managers), foreign capital ownership indicator, sources of innovation indicators, firm's size indicators, firm's age, firm's age squared, industry dummies)
Eq. (4)	=	(firm's capital stock, human capital indicator13, foreign capital ownership indicator, international competition indicator, initial level of TFP14, firm's size indicators, firm's age, firm's age squared, industry dummies)

Finally, in order to estimate the model we follow a similar approach to the one used in Griffith et al. (2006), Lööf and Heshmati (2006) and Douguet (2006). We estimate the first two equations of the model, Eq. (1) and Eq. (2), as a generalized Tobit using all firms in the sample. We follow this approach to account for potential selection of firms towards making innovation investments.

Albeit the EDIT II being a census-type survey, the sample used in the empirical analysis does not constitute a census of all Colombian industrial firms[15]. Moreover, even though the EDIT II collects information on innovation expenditures from all surveyed firms, some firms may report having made zero innovation investment when this amount is considered irrelevant or insignificant to their eyes. Hence, we estimate Equations (1) and (2) as a generalized Tobit using all firms observations and test for selection of firms towards making innovation investments. Specifically we test for the correlation of ε_i^0 and ε_i^1 to be significantly different from zero (H_0: Rho=0). We found that this is the case when restricting innovation input to be R&D expenditures

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[13] We will exclude physical capital and human capital when using TFP as dependent variable.
[14] We will include this variable only when using TFP as dependent variable
[15] EDIT II is a rider of the AMS which collects information from industrial establishments with 10 or more employees and/or an output value that exceeds $120 million in constant 2007 pesos (approximately US$57,000).

(Model 2) as well as when considering the broader notion of innovation investment (Model 1). Note also that the both Rho and the Inverse Mills Ration (Lambda) are significantly different from zero. These results are reported at the bottom of Table 4 in Section 6.

Next, we estimate the knowledge equation, Eq.(3), for each of the innovation outputs defined above using a probit model and introducing the predicted innovation input from the previous step as one of the explanatory variables. Finally, we use the predicted values of innovation output and estimate the performance equation, Eq.(4), by OLS. In the estimations of Equations 3 and 4 we only use firms reporting positive innovation spending.

Estimating the model in two steps and plugging in directly the predicted values of innovation intensity into the knowledge equation and the predicted values of innovation output into the performance equation yields inconsistent standard errors[16]. In order to correct for this and to be able to make consistent statistical inference we apply bootstrap methods to the complete two-step procedure, that is, to the estimation of the four equations as one-process only. In section 6, we report both robust standard errors as well as bootstrapped standard errors.

5 The data

5.1 Data sources

In this paper we use two plant/firm-level datasets gathered by the National Statistics Department (DANE). The first dataset collects information on innovation activities undertaken by firms during 2003 and 2004, and the second gathers longitudinal plant-level data of the manufacturing sector for the period 1997-2007. An advantage of using these datasets is that, since the innovation survey is a rider of the manufacturing survey, we are able to link them at the firm level and estimate innovation and performance related variables such as total factor productivity for each firm in the sample.

[16] It has to be noticed that this problem also results when using TFP as dependent variable in the performance equation since it is estimated outside the system.

5.1.1 Development and Technological Innovation Industrial Survey (EDIT II)

The Development and Technological Innovation Industrial Survey (EDIT II) constitutes a fundamental tool for characterizing the innovation and technological development activities of the manufacturing firms in Colombia[17]. This survey is carried out for selected years (1996, 2005 and 2007) to all industrial firms according to the directory of establishments in the Annual Manufacturing Survey (EAM). In view of the fact that EDIT II is a rider of the EAM we can merge both surveys at the firm level which is extremely useful for our research purposes. Specifically, by merging the two surveys we get information related to the innovation behavior of firms and also comprehensive information regarding the firms' production function which allows us to estimate different measures of productivity and firm performance. In the 2005 round, the EDIT II gathered information from all firms registered in the EAM 2003 accounting for 6,670 firms out of which 6,172 firms responded.

The survey consists of seven chapters, divided into three parts: the first one corresponds to the identification of the firm, location, general facts, type of organization, social capital share, number of the establishments of the firm and economic activity according to the CIIU rev. The second part, one of the most important parts of the survey, enquires about technological development activities and objectives of innovation. Lastly, the third part of the survey gathers information regarding the financial sources of technological development and innovation activities, public innovation policies and formal protection to innovation.

Within the second part of the survey, there is a chapter that collects detailed information about the investments in technological development and innovation activities undertaken by firms during 2003 and 2004. In the survey, the innovation investment is classified as follows: i) investment on capital-related technologies; ii) management-related technologies; iii) cross-cutting technologies -including patent and license acquisitions as well as ICTs; iv) R&D project; and iv) investment in technological training. Additionally, for each type of innovation investment, there is information about the objective of investment (product, process, management, or commercialization), its importance to the firm and the country of origin.

[17] DANE runs a similar survey for firms in the service sector.

In a different chapter of the second part the survey collects information about objectives, outputs and sources of ideas for technological innovation during 2003 and 2004. Particularly, the firms report information about the importance of their innovation objectives, the state of the innovation outputs (accomplished, in process, abandoned) and the factors impeding their achievement. Additionally, it collects information by types of innovation outputs: i) new or significantly improved goods or services to the firm; ii) new or significantly improved goods or services to the national market; iii) new or significantly improved goods or services to the international market; iv) new or significantly improved production process for the main production line; v) new or significantly improved production process for a complementary production line, vi) new or significantly improved management procedures and vii) new or significantly improved commercialization procedures.

Additionally, this chapter gathers information about the origin of the sources of innovative ideas, for instance, if it the source is internal or external to firm. This information is relevant for our empirical analysis and it similar information has been also used in the literature Lööf and Heshmati (2006) and Masso and Vahter (2008). Finally, in the second part of the survey there is a chapter that collects information on the firms' personnel per area or department, according to the type of appointment (permanent, temporary), genre, education level and origin. This information is relevant as well for our proposed research because it allows us calculating in a very accurately manner the human capital of the firms. In addition, this chapter collects information on investment in innovation and technological training.

In the third part of the survey there is a chapter dedicated to the financial sources for technological development and innovation activities. It collects information about the types of financing, an evaluation of the usefulness of each type and its specific problems. Additionally, in this part there of the survey there is a chapter that gathers information on the instruments of public policy oriented towards science and technology provided to firms. These chapters are of considerable importance for our research analysis since their information will allow us to study the potential financial constraints to innovation and the importance of public innovation policies.

Finally, in the third part of the survey there is a chapter dedicated to formal protections of innovation. It collects information regarding patent applications, industrial design registration, trademark registration, copyright registration and new software registration.

5.1.2 Annual Manufacturing Survey (EAM)

This survey gathers background and detailed information of the manufacturing sector, which allows a deep knowledge of its structure, characteristics and, more importantly, its evolution. The EAM is a nationwide[18] survey of industrial establishments with 10 or more employees and/or an output value that exceeds $120 million in constant 2007 pesos (approximately US$57,000 as of today). The information corresponds to the 3 and 4 digit disaggregation according to the International Standard Industrial Classification (ISIC rev. 3) adapted for Colombia. The data is available annually and in recent years more than 9,000 plants have been surveyed which gives the EAM census-like properties. This sample corresponds to industrial directories reported by the guilds and updated every year by micro-surveys to detect the appearance of new research units.

The basic concepts of this survey are the following: gross production, intermediate consumption and value added. Gross production includes products and sub-products, products in process, rental of goods, among others. Intermediate consumption includes consumption of raw materials and packaging materials (values and units required per input), energy consumption (kilowatts per hour and value) and direct and indirect costs of production. It is important to point out that this section of the survey includes the variable that captures the amount of employees in the manufacturing process. The total number of employed people is disaggregated by the worker's type of linkage to the company and by occupation categories. There is also information about salaries, wages and benefits received by each type of worker. Value added refers to the total income received by the establishment in the production process and is calculated as the difference between gross output and intermediate consumption. Additionally, there is detailed information available regarding the book value of fixed assets[19] separated by depreciable and non-depreciable assets.

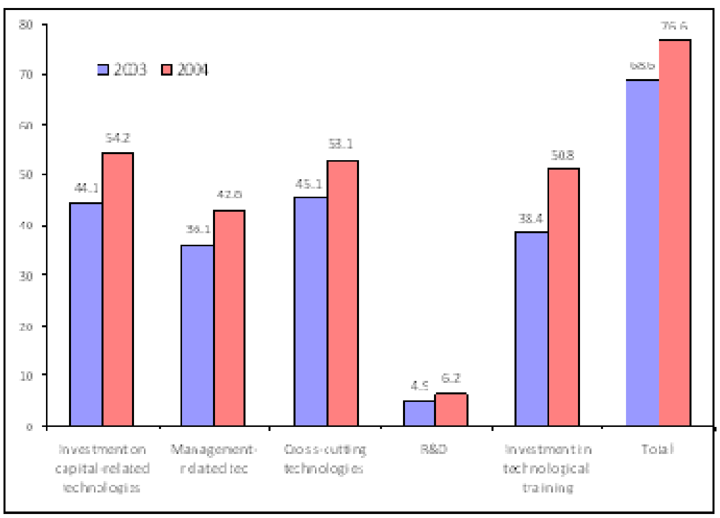
[18] Metropolitan areas and sections of the country.
[19] It refers to those assets that are not intended for sale.

5.2 Data descriptive analysis

In this section we present descriptive statistics of the main variables of the model. The purpose of this exercise is to have a first approximation of the variables that will serve as a guide for the model specification. We start the exercise with the dependent variables (innovation decision, input and output) and then we present some of the explanatory variables.

The dependent variable of the first equation is a dummy taking the value of one if the firm invested in innovation and zero otherwise. In Figure 9 we present the percentage of firms that invested in innovation. As can be observed, 77% of the firms reported having invested in any type of innovation in 2004 up from 69% in 2003. Also, around half of the firms in 2004 reported having invested in some type of innovation except in the case of R&D, for which only 6% of firms (382 firms) reported having invested in this type of activity.

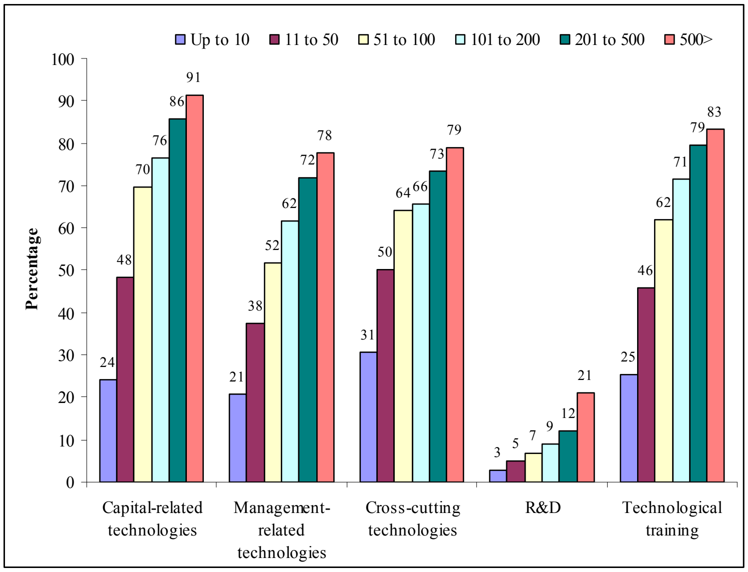
Figure 9: Share of firms that invested in innovation



Source: EDIT II

In Figure 10 we present the share of the firms that invested in each type of innovation input by size. As can be observed, innovation investment increases with firm size. For example, while only 24% of the smallest firms invest in capital-related technologies, 91% of the largest firms invest in those technologies. This pattern is more marked in the case of investment in R&D: only 3% of the smallest firms invest in R&D compared to 21% of the largest firms.

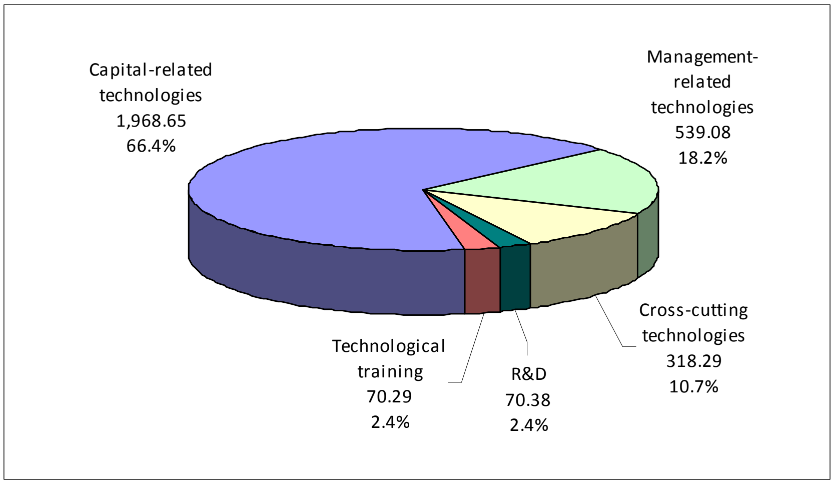
Figure 10: Share of firms that invested in innovation by size



Source: EDIT II

Next we present the dependent variable of our second equation, innovation intensity, that is, the amount invested by firms in innovation. Figure 11 shows the distribution of innovation investment by type in 2004 and the amount invested in 2003 million pesos. It is important to mention that this composition has barely changed between 2003 and 2004. Most of the investment goes to capital-related technologies (66%), then to management-related technologies (18%) and cross-cutting technologies (11%). Note that investment in technological training and R&D amount only to 4.7%, which can be considered a low amount if the country were to boost innovation output and productivity in the future.

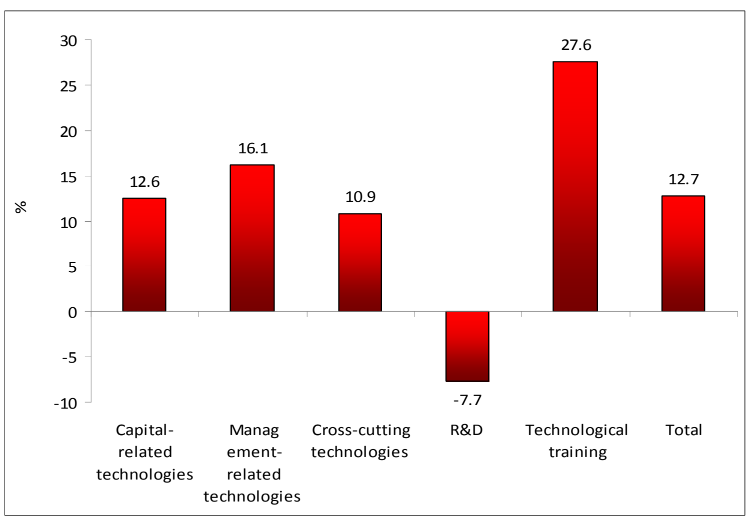
Figure 11: Distribution of innovation intensity by types



2003 Colombian pesos, Millions.
Source: EDIT II (2004)

In Figure 12 we present the percentage change in innovation input between 2003 and 2004. In total, firms invested $1,968.65 million pesos in 2004 up from $1,748.99 a 13% increase in real terms. This change, however, was not uniform across types: investment in technological training increased by 28%, while investment in R&D decreased by 8%. Investment in managerial-related technologies, capital-related and cross-cutting technologies increased by 16%, 13% and 11%, respectively.

Figure 12: Change in innovation intensity by type 2003-2004

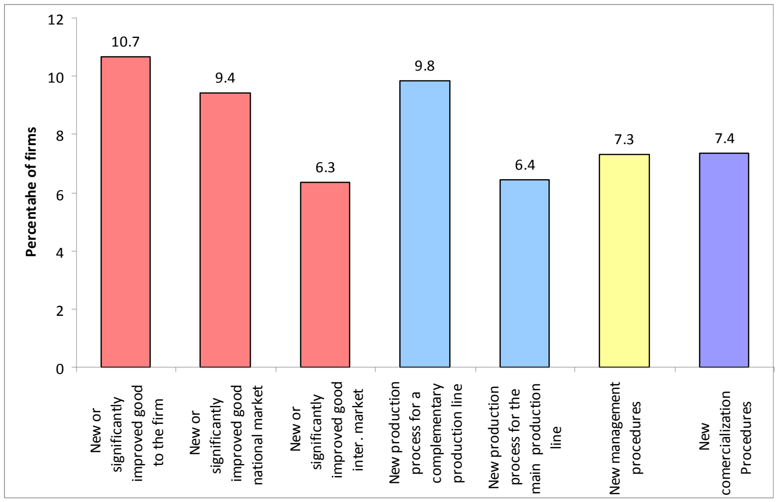


Source: EDIT II

Finally in Figure 13 we present the dependent variable for our third equation, innovation output, expressed in terms of percentage of firms that reported successfully achieving innovation output by type. As can be observed in the graph, the number of firms actually innovating is not large. It is worth noting that there is a considerable variation among types of innovation, which validates our interest in estimating the effect of each type of innovation on productivity separately. For example, looking at innovation of good and services (columns in pink), the percentage of firms that produce them new or significantly improved to the firms is 11%, while to the national market is 9% and to the international market is only 6%. This serves as evidence that in Colombia there is more incremental innovation than radical innovation which, in turn, may have different effects on productivity. One may expect the effect of radical innovation to be stronger especially if it is concentrated in the international market. In our empirical work we test this hypothesis.

Looking at innovation in the production process, the columns in light blue, we observe that there are more firms with innovative output in the process of the complementary production line than in the main production line. This behavior does not seem very intuitive and further analysis should be done to understand it by exploring, for example, the relationship between innovation intensity and this particular output. Also, one would expect different effects from this behavior on productivity. Finally, looking at the last two columns in the figure (yellow and dark blue) one observes that the share of firms obtaining innovative output in the management and commercialization procedures is similar to those obtaining innovative output of other types, which corroborates the importance of keeping them separately in the empirical analysis.

Figure 13: Innovation output by type



Source: EDIT II

6 Empirical results

In this section we present the results of estimating the four equations of the model described in Section 2. The statistics of the variables used in the estimations are shown in Table 3.

Table 3: Descriptive Statistics

	TOTAL FIRMS				INNOVATIVE FIRMS				NON-INNOVATIVE FIRMS			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Innovation Intensity	6.50	1.72	-1.25	11.75	6.49	1.72	-1.25	12.13				
Innovation Engage	1.00	0.00	1.00	1.00	0.75	0.43	0.00	1.00				
R&D Intensity	5.05	1.34	0.78	8.52	4.83	1.44	-1.85	8.51				
R&D Engage	0.07	0.25	0.00	1.00	0.05	0.22	0.00	1.00				
Aggregate Innovation Output	0.86	0.35	0.00	1.00	0.65	0.47	0.00	1.00	0.06	0.23	0.00	1.00
Innovation in Processes	0.60	0.49	0.00	1.00	0.45	0.49	0.00	1.00	0.03	0.16	0.00	1.00
Innovation in management and marketing	0.57	0.49	0.00	1.00	0.43	0.49	0.00	1.00	0.03	0.18	0.00	1.00
Goods and Services Adaptation	0.66	0.47	0.00	1.00	0.50	0.50	0.00	1.00	0.04	0.20	0.00	1.00
Goods and Services Innovation	0.22	0.41	0.00	1.00	0.16	0.36	0.00	1.00	0.01	0.10	0.00	1.00
log(sales/workers)2004	10.74	1.07	2.37	14.79	10.78	1.07	2.17	18.02	10.51	0.99	2.18	14.10
log(sales/workers)2005	10.80	1.10	2.24	15.32	10.79	1.11	-0.21	17.82	10.54	1.04	-0.21	14.18
log(sales/workers)2006	10.89	1.11	-0.61	15.51	10.88	1.12	-0.60	17.77	10.62	1.08	-0.44	14.66
Log(tfp)2004	7.02	1.02	-1.27	11.37	6.99	1.02	-1.57	12.82	6.87	1.00	-1.57	12.87
Log(tfp)2005	7.04	1.02	-2.13	12.79	7.00	1.03	-3.90	12.73	6.90	1.03	-3.91	10.09
Log(tfp)2006	7.08	0.97	-0.29	11.72	7.04	1.00	-4.02	12.53	6.95	1.05	-4.02	10.34
International Competition	0.07	0.17	0.00	1.00	0.06	0.16	0.00	1.00	0.04	0.14	0.00	1.00
Foreign capital indicator	3.47	16.91	0.00	100.00	2.86	1.54	0.00	10.00	1.39	10.90	0.00	100.00
Formal Protection Firm	0.19	0.39	0.00	1.00	0.15	0.35	0.00	1.00	0.07	0.25	0.00	1.00
Formal Protection Sector	17.67	29.88	0.00	122.00	15.71	27.90	0.00	122.00	14.45	25.01	0.00	122.00
Capital stock	9.51	1.32	2.42	14.51	9.43	1.36	2.42	16.44	9.29	1.41	3.88	13.66
Market share	0.01	0.03	0.00	0.77	0.01	0.02	0.00	0.77	0.00	0.02	0.00	0.43
Age (days)	7434	4471	11	34162	7297	434	11	34162	7122	3967	106	33900
Skills	0.35	0.20	0.00	1.00	0.34	0.21	0.00	2.00	0.37	0.23	0.00	2.00
Inicial ltfp	7.00	0.85	-1.60	12.95	6.94	0.87	-2.65	13	6.84	0.84	-0.11	13.00
Human capital indicators												
Engineers	0.16	0.24	0.00	1.00	0.15	0.25	0.00	1.00	0.13	0.27	0.00	1.00
Managers	0.58	0.31	0.00	1.00	0.58	0.31	0.00	1.00	0.58	0.35	0.00	1.00
Public policy												
National Innovation System	0.02	0.14	0.00	1.00	0.01	0.11	0.00	1.00	0.00	0.00	0.00	0.00
Competitiveness and productive development instruments	0.06	0.23	0.00	1.00	0.04	0.19	0.00	1.00	0.00	0.00	0.00	0.00
Occupational training and other education programs	0.04	0.19	0.00	1.00	0.02	0.15	0.00	1.00	0.00	0.00	0.00	0.00
Standardization, accreditation and quality related instruments	0.04	0.20	0.00	1.00	0.02	0.17	0.00	1.00	0.00	0.00	0.00	0.00
Firm-related funds	0.03	0.18	0.00	1.00	0.02	0.15	0.00	1.00	0.00	0.03	0.00	1.00
Size												
Medium	0.29	0.45	0.00	1.00	0.24	0.42	0.00	1.00	0.11	0.32	0.00	1.00
Large	0.06	0.24	0.00	1.00	0.05	0.22	0.00	1.00	0.01	0.11	0.00	1.00
Sources												
Intenal sources	0.81	0.39	0.00	1.00	0.79	0.4	0.00	1.00	0.55	0.50	0.00	1.00
Other firms' sources	0.32	0.47	0.00	1.00	0.31	0.46	0.00	1.00	0.14	0.34	0.00	1.00
Specialized groups	0.11	0.31	0.00	1.00	0.03	0.17	0.00	1.00	0.03	0.18	0.00	1.00
External relationships	0.32	0.47	0.00	1.00	0.3	0.45	0.00	1.00	0.08	0.27	0.00	1.00
No. Obs	4,210				3,822				388			

Source: DANE and uthor's calculations

Before going through the results, it is worth noting that for studying the role played by innovation in productivity we estimated two different models in order to identify the impact on productivity of two kinds of innovation: on the one hand the overall innovation, that is the sum of all innovating efforts (Model I), and on the other hand innovation exclusively in R&D (Model II).

The first set of equations in Table 4 corresponds to the decisions by firms of investing in innovation (Equation 0), and the amount they invest in such activities conditional on having decided to invest, that is innovation Intensity (Equation 1). Both equations include the same explanatory variables except for the set of variables indicating sources of innovation which is only included in the innovation intensity equation, and size dummy variables which are only included in the decision to innovate. The results from the two models (marginal effects) are presented in columns 2 and 3. Note that the selection equation is the same in both models, since it is not affected by the kind of innovation effort.

We find that firms' size is positively related to the decision to innovate: large and medium firms innovate more than small firms. Similarly, firms with greater market participation are more likely to invest in innovation and invest greater amounts, even in R&D.

Regarding the exporting variable (international competition) we assume in our model that exports may cause innovation. However, we recognize that the causality of the relation between innovation and exports is ambiguous. According to trade models (e.g. Krugman, 1979), innovation is the driving force for exports. But at the same time, the endogenous growth models (e.g. Grossman and Helpman 1991) predict that there is also a reverse effect since exports may themselves cause innovative activities[20]. The first causality assumes that successful innovation translates into export performance for internationalizing firms, in other words, better firm performance tends to precede exporting. The second causality, the one considered in our model, supposes that there is a diffusion of the innovative technology embodied in the exported products, that is, firms learn from trade in terms of innovation (*learning-by-exporting hypothesis*) and exporting firms continuously improve their innovation activities to remain competitive in international markets. Indeed, we find a positive relation between exports and innovation in the sense that exporting firms are more likely to innovate, and invest more in these activities, even in R&D.

Firms with foreign ownership tend to invest greater amounts in innovation, but this feature is not relevant for taking the decision to innovate. The positive relation between innovation and foreign-capital ownership is quite common in the empirical literature based on the positive impacts of Foreign Direct Investment and is explained by different factors: firms can

[20] Although there has been an effort to disentangle the causality of the relation between these two variables the double-way effect is also empirically proved. An example of the causal effect of innovation on exports can be found in Lachenmaier, S. and L. Wößmann, "Does innovation cause exports? Evidence from exogenous innovation impulses and obstacles", Oxford. Economic Papers, 2006; 58: 317-350.

have access to international technology and knowledge at lower costs (technology and knowledge transfer), so they are less dependent on sourcing knowledge locally, and foreign-owned companies have a larger selection of potential sources they can draw from to finance their innovation activities. However, we find that foreign-owned do not invest more in R&D, which suggest that, as in the case of multinational companies, R&D activities may be carried out outside the country, for example in the company's headquarters.

Capital intensive firms are more prone to innovate and spend larger amounts in innovating efforts, although this result is less clear in the case of R&D.

Human capital appears to be highly relevant for innovation. Firms that have skilled engineers not only are more prone to innovate, but also invest larger amounts. Skilled managers boost the amount invested in innovation, but strangely it has a negative effect on the likelihood of innovation.

With regards to the sources of ideas, when ideas for innovation come from internal sources, other firms' sources and especially from external relationships (e.g. universities, consultants and information systems), innovation intensity is higher. Surprisingly, the influence of ideas coming from specialized groups (Chambers of Commerce) appears to be negative. In the case of R&D none of the sources appear to affect innovation activities.

The availability of public instruments for innovation increases the probability that firms decide investing in innovation. In particular, instruments aiming at promoting competitiveness and productive development programs (Proexport, for example) have the strongest effect, but the National Innovation System, training-related programs, supports for standardization and accreditation and the access to other firms-related instruments also have a significant effect. Interestingly, we find that the impact of public policy instruments in much less evident in the amount invested in innovation, except for the access to instruments associated with competitiveness and productive development and in a lesser degree training and educational programs. However, an important result is that none of the public policy instruments influence the amounts invested in R&D.

Finally, the use of formal protection methods by the firm (patents and utility models solicited) increases the probability of innovating in R&D and the amounted invested. However, this variable does not affect other kind of innovation activities.

Table 4: Selection and Innovation Equations

VARIABLES	Model I		Model II	
	Decision to innovate (i)	Innovation intensity (ii)	Decision to innovate in R&D (i)	Innovation intensity in R&D (ii)
International Competition	0.5032	0.385	0.1255	-1.1369
	(0.1583)***	(0.1550)***	(0.1769)	(0.5148)**
	[0.0961]***	[0.1502]**	[0.1634]	[0.5377]**
Foreign capital indicator	0.0017	0.0059	-0.0027	-0.0026
	(0.0017)	(0.0013)***	(0.0014)*	(0.0040)
	[0.0010]*	[0.0011]***	[0.0015]*	[0.0048]
Formal Protection Firm	0.0390	-0.0268	-0.0528	-0.2269
	(0.0555)	(0.0405)	(0.0345)	(0.0780)***
	[0.0348]	[0.0283]	[0.0679]***	[0.2231]***
Formal Protection Sector	0.6861	0.2812	0.3323	0.7346
	(0.0805)***	(0.0724)***	(0.0700)***	(0.2192)***
	[0.0469]***	[0.0675]***	[0.0302]*	[0.0506]***
Capital stock	0.0416	0.1169	0.0174	0.0868
	(0.0115)***	(0.0154)***	(0.0178)	(0.0520)*
	[0.0081]***	[0.0172]***	[0.0174]	[0.0464]*
Market share	5.0135	3.3385	2.0163	4.0063
	(2.0552)**	(0.7071)***	(0.8105)**	(1.7034)**
	[1.1348]***	[0.6751]***	[0.7586]***	[1.4703]***
Human capital indicator				
Engineers	0.2366	0.9294	0.2808	1.1118
	(0.0946)**	(0.1192)***	(0.1274)**	(0.3831)***
	[0.0555]***	[0.1237]***	[0.1137]**	[0.3484]***
Managers	-0.1014	0.3058	0.1266	0.586
	(0.0733)	(0.0943)***	(0.1079)	(0.3323)*
	[0.0451]**	[0.0945]***	[0.0988]	[0.3167]*
Public policy				
National Innovation System	6.6052	0.1077	0.2374	0.5690
	(0.1222)***	(0.1558)	(0.1758)	(0.4376)
	[0.1224]***	[0.1540]	[0.1833]	[0.4224]
Competitiveness and productive development instruments	7.2254	0.2311	0.3969	0.0509
	(0.3043)***	(0.0997)**	(0.1158)***	(0.2959)
	[0.3056]***	[0.0992]**	[0.1187]***	[0.3716]
Occupational training and other education programs	7.4189	0.1563	0.0557	0.5335
	(0.2026)***	(0.1185)	(0.1483)	(0.3740)
	[0.2029]***	[0.1178]	[0.1489]	[0.3419]
Standardization, accreditation and quality related instruments	6.5471	0.2157	0.1969	0.3828

	(0.0951)***	(0.1042)**	(0.1195)*	(0.3140)
	[0.0931]***	[0.1067]**	[0.1176]*	[0.3343]
Firm-related funds	1.5996	0.361	0.1390	0.4336
	(0.0665)***	(0.1280)***	(0.1432)	(0.3878)
	[0.0683]***	[0.1255]***	[0.1463]	[0.3285]
Sources				
Intenal sources		0.4743		-0.1162
		(0.0672)***		(0.2423)
		[0.0746]***		[0.2437]
Other firms sources		0.1958		-0.0170
		(0.0596)***		(0.1662)
		[0.0562]***		[0.1646]
Specialized groups		-0.1787		-0.2130
		(0.0871)**		(0.2116)
		[0.0839]**		[0.2078]
External relationships		0.4346		0.2590
		(0.0614)***		(0.1770)
		[0.0578]***		[0.1828]
Age	-0.0000***	-0.0001***	0.0000	-0.0000
	(0.0000)***	(0.0000)***	(0.0000)	(0.0001)
	[0.0000]***	[0.0000]***	[0.0000]	[0.0001]
Age squared	0.0000	0.0000	-0.0000	0.0000
	(0.0000)*	(0.0000)**	(0.0000)	(0.0000)
	[0.0000]***	[0.0000]**	[0.0000]	[0.0000]
Size				
Medium	0.6698		0.1854	
	(0.0605)***		(0.0644)***	
	[0.0347]***		[0.0619]***	
Large	1.0555		0.5456	
	(0.1403)***		(0.0941)***	
	[0.0840]***		[0.0954]***	
Rho		-0.2069		0.8031
		(0.0863)		(0.0795)
Lambda (Inverse Mills Ratio)		-0.3376 (0.1428)		1.4995 (0.3357)
Wald Test of independent eq. (rho=0) $\chi^2(1)$		6.43		24.43
p-value		0.0112		0.0000
Total Observations		5934		5934
Censored Observations (observed innovation input=0)		1302		5557
Uncensored Observations (observed innovation input>0)		4632		377

*** p<0.01, ** p<0.05, * p<0.1. All regressions include sector dummies. Marginal effects reported. Robust standard errors in () and Bootstrap standard errors in [].

Next, we present results from estimating the knowledge equation (Equation 3) for four types of innovation outputs and for the aggregate. The first type corresponds to the production of goods and services that are new or significantly improved to the firm or to the national market, which will considered as adaptation since it does not strictly entail the creation of new knowledge but the imitation of products and services that already exist in the national or international market. The second type of innovation output refers to the production of goods and services that are new or significantly improved to the international market. We will consider this type as "true" innovation of goods and services since it entails novelty and it has the potential of being patented. The third type of innovation output is related to the adoption of new or significantly improved production methods, which may imply changes in equipment or in the way production is organized, or they result from the use of new knowledge. Finally, the fourth type of innovation output refers to changes in the firm's managerial activities, or in the product commercialization or packaging methods.

Table 5 shows results for of the four types of innovation output defined above and for the aggregate. All dependent variables are defined as dummy variables taking the value of one if the firm reports having obtained at least one innovation output and zero otherwise. All regressions include the same set of explanatory variables in addition to industry dummies. The numbers in the table correspond to marginal effects from Probit estimations.

We find that predicted innovation intensity increases the probability of obtaining all innovation outputs. Looking at the different types of innovation output one finds that the greater effect of investing in innovating (23 percent), followed by adaptation (15 percent) and then innovation in processes (13 percent). In the second model, investing in innovation only has an effect in R&D Aggregate Innovation Output.

In terms of firm size, we find that larger firms are more prone to obtain innovation output than smaller ones. Large-size firms are between 7 and 8 percent more likely to obtain innovation output, except for the case of innovation in goods and services where this percentage comes to 22 percent and medium-size firms are more prone to produce new or significantly improved goods and services to the international market (11 percent). Results related to firm size in the R&D model are similar in the case of goods and services' innovation and adaptation.

Concerning the sources of ideas for innovation as determinants of innovation output, we find that the probability of obtaining innovation outputs in management and marketing as well as in processes increases when innovation ideas come from other firms' sources - such as the firm's headquarters, competitors, suppliers or clients – and from universities and other external sources. Other firms' sources also influence goods and services' adaptation and external sources influence goods and services innovation. Looking at the model with R&D, the influence of the different sources of ideas is much less evident, but specialized groups source has a positive impact on innovating in goods and services.

We also find some puzzling results: firms with foreign capital are less likely to obtain innovation outputs even though they invest more intensively; firms with greater capital stock reach lesser innovation outputs, although they tend to invest more in innovation; and firms with larger shares of skilled labor are less likely to attain innovations in goods and services and in production processes, even though they innovate more intensively. In contrast, when firms invest in R&D foreign capital indicator and a higher share of managers positively affect aggregate innovation output.

Table 5: Knowledge Equation

VARIABLES	Innovation - Model I					R&D - Model II				
	Aggregate Innovation Output	Goods and Services Adaptation	Goods and Services Innovation	Innovation in Processes	Innovation in management and marketing	Aggregate Innovation Output	Goods and Services Adaptation	Goods and Services Innovation	Innovation in Processes	Innovation in management and marketing
Innovation intensity (predicted)	0.0644	0.1583	0.2318	0.1299	0.0618	0.0726	0.0575	0.0068	0.0089	0.0131
	(0.0330)*	(0.0383)***	(0.0370)***	(0.0403)***	(0.0368)*	(0.0380)*	(0.0552)	(0.0629)	(0.0439)	(0.0429)
	[0.0263]**	[0.0371]***	[0.0309]***	[0.0375]***	[0.0365]*	[0.0427]*	[0.0430]	[0.0531]	[0.0431]	[0.0523]
Foreign capital indicator	-0.0009	-0.0013	-0.0005	-0.0009	-0.0005	-0.0017	-0.0015	0.0002	-0.0014	0.0005
	(0.0003)***	(0.0004)***	(0.0004)	(0.0004)**	(0.0006)	(0.0009)*	(0.0014)	(0.0014)	(0.0013)	(0.0015)
	[0.0003]***	[0.0005]***	[0.0004]	[0.0005]*	[0.0005]	[0.0009]**	[0.0011]	[0.0015]	[0.0011]	[0.0014]
Capital stock	-0.0057	-0.0159***	-0.0215	-0.0128	-0.0038	0.0186	-0.0023	0.0070	0.0011	-0.0074
	(0.0055)	(0.0049)***	(0.0066)***	(0.0070)*	(0.0068)	(0.0127)	(0.0253)	(0.0302)	(0.0137)	(0.0152)
	[0.0044]	[0.0063]**	[0.0057]***	[0.0065]**	[0.0065]	[0.0155]	[0.0164]	[0.0214]	[0.0164]	[0.0186]
Human capital indicator										
Engineers	0.0022	-0.0576	-0.1645	-0.1008**	0.0226	0.2613*	0.2339	0.2154	0.0066	0.1553
	(0.0402)	(0.0513)	(0.0414)***	(0.0474)**	(0.0488)	(0.1396)*	(0.1993)	(0.1563)	(0.1417)	(0.1853)
	[0.0349]	[0.0493]	[0.0429]***	[0.0501]**	[0.0500]	[0.1383]*	[0.1491]	[0.1662]	[0.1296]	[0.1567]
Managers	-0.0445	-0.0271	-0.0184	-0.0422	-0.0076	0.0031	-0.0243	-0.0312	-0.0643	-0.0753
	(0.0181)**	(0.0269)	(0.0294)	(0.0281)	(0.0276)	(0.0712)	(0.0755)	(0.1330)	(0.1122)	(0.1202)
	[0.0203]**	[0.0295]	[0.0274]	[0.0309]	[0.0310]	[0.0853]	[0.1045]	[0.1348]	[0.1021]	[0.1138]
Age	-0.0000	0.0000	0.0000	0.0000	0.0000	-0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)*	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	[0.0000]	[0.0000]*	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]*	[0.0000]	[0.0000]	[0.0000]
Age squared	0.0000	-0.0000	-0.0000	-0.0000	-0.0000	0.0000	-0.0000	0.0000	0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	[0.0000]	[0.0000]*	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Sources										
Intenal sources	0.0083	0.0073	-0.0241	0.0512	0.0225	-0.0265	-0.0089	0.1599	0.1240	-0.0006
	(0.0220)	(0.0252)	(0.0251)	(0.0307)*	(0.0274)	(0.0449)	(0.0815)	(0.0799)**	(0.0874)	(0.0935)
	[0.0185]	[0.0264]	[0.0257]	[0.0278]*	[0.0274]	[0.0569]	[0.0796]	[0.0972]	[0.0960]	[0.0872]
Other firms sources	0.0258	0.0323	-0.0009	0.0821	0.0537	-0.0109	0.0542	0.0320	-0.0637	-0.0697
	(0.0136)*	(0.0182)*	(0.0164)	(0.0200)***	(0.0177)***	(0.0409)	(0.0517)	(0.0638)	(0.0586)	(0.0586)
	[0.0128]**	[0.0188]*	[0.0169]	[0.0193]***	[0.0196]***	[0.0468]	[0.0577]	[0.0711]	[0.0528]	[0.0599]
Specialized groups	-0.0035	0.0183	0.0399	-0.0088	0.0110	-0.0683	-0.0376	-0.1754***	-0.0670	-0.0278
	(0.0156)	(0.0344)	(0.0300)	(0.0222)	(0.0310)	(0.0862)	(0.0877)	(0.0664)***	(0.0725)	(0.0860)
	[0.0190]	[0.0261]	[0.0248]	[0.0279]	[0.0277]	[0.0902]	[0.0813]	[0.0817]**	[0.0794]	[0.0841]
External relationships	0.0013	0.0068	-0.0436	0.0534	0.0725	0.0776	0.0773	0.0653	0.0500	0.1456
	(0.0185)	(0.0278)	(0.0204)**	(0.0254)**	(0.0250)***	(0.0666)	(0.0617)	(0.0655)	(0.0635)	(0.0770)*
	[0.0179]	[0.0252]	[0.0209]**	[0.0255]**	[0.0252]***	[0.0564]	[0.0658]	[0.0780]	[0.0622]	[0.0702]**
Size										
Medium	0.0030	0.0174	0.111	0.0289	0.0356	-0.0755	-0.0542	0.0429	-0.0644	-0.0157
	(0.0106)	(0.0171)	(0.0169)***	(0.0150)*	(0.0192)*	(0.0604)	(0.0631)	(0.0565)	(0.0643)	(0.0818)
	[0.0118]	[0.0172]	[0.0173]***	[0.0181]	[0.0183]*	[0.0686]	[0.0679]	[0.0803]	[0.0668]	[0.0701]
Large	0.0296	0.0773	0.2137	0.0817	0.0809	0.0856***	0.1254**	0.3855***	0.0876	0.1489
	(0.0174)*	(0.0259)***	(0.0266)***	(0.0340)**	(0.0233)***	(0.0276)***	(0.0632)**	(0.0858)***	(0.0824)	(0.0763)*
	[0.0172]*	[0.0259]***	[0.0299]***	[0.0276]***	[0.0282]***	[0.0459]*	[0.0681]*	[0.0916]***	[0.0706]	[0.0740]**
Observations	4632	4632	4632	4632	4632	377	377	377	377	377

*** p<0.01, ** p<0.05, * p<0.1. All regressions include sector dummies. Marginal effects reported. Robust standard errors in () and Bootstrap standard errors in [].

Finally we present results from estimating the performance equations, using both productivity (TFP) and sales per worker as dependent variables. Equations were intended to capture the contemporaneous effect of innovation on productivity (2004) and the lagged effect (2005 and 2006). Table 6 shows the impact of each type of predicted innovation output on firms' productivity and on sales per worker, and Table 7 shows the impact of the aggregate measure of predicted innovation output on the same dependent variables.

We don't find a significant effect of any innovation output on productivity and only a positive impact of innovation in processes in TFP in the R&D model. However, adaptation in goods and services positively affects firms' performance when using sales per worker that lasts three years. However, when investment is done exclusively in R&D, adaptation has an effect on firms' performance one year lagged. In addition, goods and services innovation (new to the international market) positively influences the performance of firms the same year the innovation takes place but it disappears over the following years. Innovation in processes appears to negatively influence firms' performance, but positively when investment is done in R&D.

We find other results that are common in the literature (Arbeláez et al 2006): size is positively related to productivity, and physical capital stock and human capital are associated with larger sales. We also find that firms with foreign ownership are more productive. This result is consistent with the fact that foreign-owned firms invest more in innovation (see Table 3), due to technology and knowledge transfers, and the greater access to funds to finance innovation activities.

Finally, the variable related to exports (international competition) has a significant contemporaneous effect on productivity, i.e. in 2004. It is worth noting that in our estimations we assume this causality form exports to productivity, but we are aware of the possible reverse effect. We base our assumption on the *learning- by –exporting hypothesis* through which firms learn as a consequence of exporting and increase their productivity. As we argued in the case of the innovation equation the *learning-by-exporting hypothesis* firms learn from trade in terms of innovation so that they improve their innovation activities, which may result in improvements in productivity. Thus, innovation - and the positive relation between innovation and exporting firms- helps to explain the positive association that we found between exports and productivity.

Table 6: Performance Equations for types of innovation Outputs

	Model I Innovation			Model II R&D		
	TFP			TFP		
VARIABLES	2004	2005	2006	2004	2005	2006
Adaptation	0.2834	0.1960	0.0351	0.4325	0.4116	0.0039
	(0.4735)	(0.5338)	(0.6079)	(0.9547)	(0.6555)	(0.8043)
	[0.5037]	[0.5212]	[0.6780]	[0.8522]	[0.5395]	[0.7471]
Innovation	-0.1086	-0.0543	-0.0768	0.3452	-0.0205	0.0801
	(0.2131)	(0.2499)	(0.2374)	(0.3571)	(0.3869)	(0.4411)
	[0.2245]	[0.2313]	[0.2232]	[0.3483]	[0.4331]	[0.5106]
Innovation in Processes	0.0323	-0.0790	0.1874	1.4011*	0.697	0.1722
	(0.3452)	(0.3327)	(0.3946)	(0.7111)*	(0.7311)	(0.8580)
	[0.3672]	[0.3937]	[0.5202]	[0.6820]**	[0.6467]	[0.9281]
Innovation in management and marketing	-0.2863	-0.1128	-0.3538	-0.4678	-0.5519	-0.9639
	(0.2989)	(0.3952)	(0.4841)	(0.3817)	(0.5835)	(0.7868)
	[0.4257]	[0.4743]	[0.6355]	[0.5361]	[0.6287]	[0.9665]
International competition indicator	0.1135	0.0359	0.0411	0.1157	-0.0113	-0.1995
	(0.0571)*	(0.0700)	(0.0771)	(0.3326)	(0.3542)	(0.3751)
	[0.0668]*	[0.0637]	[0.0726]	[0.3076]	[0.2624]	[0.3564]
Foreign capital indicator	0.0008	0.0007	0.0015	-0.0007	0.0007	0.0023
	(0.0005)	(0.0007)	(0.0006)**	(0.0017)	(0.0018)	(0.0023)
	[0.0005]	[0.0006]	[0.0006]**	[0.0019]	[0.0018]	[0.0026]
Initial TFP	0.9023	0.8459	0.7655	0.8752	0.8118	0.7796
	(0.0232)***	(0.0250)***	(0.0277)***	(0.0409)***	(0.0529)***	(0.0645)***
	[0.0169]***	[0.0219]***	[0.0214]***	[0.0559]***	[0.0602]***	[0.0626]***
age	-0.0000	-0.0000	-0.0000	0.0000	0.0000	0.0001
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
age2	0.0000	0.0000	0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Size						
Medium	-0.0060	-0.0119	0.0233	-0.2278	-0.0927	0.0487
	(0.0313)	(0.0326)	(0.0338)	(0.1623)	(0.1149)	(0.1316)
	[0.0281]	[0.0303]	[0.0339]	[0.1499]	[0.1155]	[0.1354]
Large	-0.0162	-0.0442	-0.0157	-0.0604	-0.0198	0.0223
	(0.0462)	(0.0691)	(0.0699)	(0.1247)	(0.1793)	(0.2334)
	[0.0402]	[0.0510]	[0.0550]	[0.1324]	[0.1780]	[0.2118]
Constant	1.0202	1.5175	1.7077	1.9789	2.1932	2.2125
	(0.2229)***	(0.1825)***	(0.2428)***	(0.6873)***	(0.4439)***	(0.6022)***
	[0.2966]***	[0.4949]***	[0.4166]***	[0.8122]**	[0.6270]***	[0.7747]***
Observations	4632	4632	4632	377	377	377
R-squared	0.706	0.634	0.567	0.687	0.696	0.626

*** p<0.01, ** p<0.05, * p<0.1. All regressions include sector dummies. Robust standard errors in () and Bootstrap standard errors in [].

Table 6: Performance Equations for types of innovation Outputs (Continued)

	Model I INNOVATION			Model II R&D		
	Sales per worker			Sales per worker		
VARIABLES	2004	2005	2006	2004	2005	2006
Adaptation	3.002	4.6135	4.0799	1.4784	3.3139	3.0387
	(1.0810)***	(1.4737)***	(2.7046)	(0.9762)	(2.1586)	(2.9592)
	[0.8377]***	[1.6421]***	[2.2827]*	[1.1959]	[2.0092]*	[2.6178]
Innovation	0.9793	0.7556	0.8133	0.6110	1.2623	1.3859
	[0.5221]*	[0.8270]	[1.0714]	[0.8954]	[0.9824]	[1.9209]
	(0.3122)***	(0.6906)	(1.0492)	(0.7747)	(1.3537)	(1.6592)
Innovation in Processes	-2.7990	-2.0610	-2.4768	1.6194	2.4872	3.3771
	(0.5598)***	(1.0314)*	(1.3506)*	(0.9406)*	(1.4149)*	(2.3279)
	[0.6218]***	[1.1140]*	[1.6724]	[1.1335]	[1.5041]*	[2.1298]
Innovation in management and marketing	0.2760	-1.6458	0.7125	-0.3658	0.4003	0.5036
	(0.7653)	(1.3302)	(2.1295)	(1.0902)	(1.1694)	(1.5431)
	[0.6760]	[1.2213]	[2.0328]	[1.1102]	[1.3943]	[1.6487]
International competition indicator	0.5356	0.4035	0.4712	0.5154	-0.1388	-0.2009
	(0.1712)***	(0.2876)	(0.3365)	(0.2292)**	(0.8114)	(0.8556)
	[0.0987]***	[0.2171]*	[0.2885]	[0.4026]	[1.2863]	[1.2807]
Foreign capital indicator	0.0052	0.0051	0.0002	0.0002	-0.0030	-0.0097
	(0.0011)***	(0.0016)***	(0.0032)	(0.0029)	(0.0041)	(0.0101)
	[0.0009]***	[0.0017]***	[0.0026]	[0.0036]	[0.0059]	[0.0089]
Capital stock	0.1031	0.1728	0.18	0.1581	0.1912	0.3164
	(0.0173)***	(0.0353)***	(0.0344)***	(0.0899)*	(0.1041)*	(0.1755)*
	[0.0117]***	[0.0305]***	[0.0369]***	[0.0592]***	[0.1135]*	[0.1401]**
Human capital indicator	0.5082	0.7858	1.1336	0.9516	1.1114	0.7907
	(0.2270)**	(0.3039)**	(0.2514)***	(0.4552)**	(0.7105)	(0.9954)
	[0.1116]***	[0.1959]***	[0.2917]***	[0.4258]*	[1.0066]	[0.8135]
age	-0.0001	-0.0000	0.0000	0.0001	0.0002	0.0002
	(0.0000)***	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0002)
	[0.0000]***	[0.0000]	[0.0000]	[0.0001]	[0.0001]*	[0.0001]*
age2	0.0000	0.0000	0.0000	-0.0000	-0.0000	-0.0000
	(0.0000)***	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	[0.0000]***	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Size						
Medium	0.0963	0.3040	0.2913	-0.0341	-0.1698	-0.2128
	(0.0727)	(0.0984)***	(0.1157)**	(0.2216)	(0.3267)	(0.3983)
	[0.0417]**	[0.0994]***	[0.1492]*	[0.1935]	[0.3269]	[0.4535]
Large	0.0724	0.2138	0.3414	0.3897	0.3951	0.3203
	(0.1167)	(0.1960)	(0.2370)	(0.3850)	(0.4064)	(0.7118)
	[0.0659]	[0.1504]	[0.2066]*	[0.3050]	[0.4697]	[0.6534]
Constant	9.4621	8.3523	7.3461	10.9005	11.3065	10.6662
	(0.2038)***	(0.4026)***	(0.4443)***	(1.1056)***	(1.2408)***	(1.8093)***
	[0.8321]***	[0.9078]***	[2.4297]***	[1.2860]***	[1.9110]***	[2.2900]***
Observations	4632	4632	4632	377	377	377
R-squared	0.397	0.178	0.123	0.531	0.380	0.306

*** p<0.01, ** p<0.05, * p<0.1. All regressions include sector dummies. Robust standard errors in () and Bootstrap standard errors in [].

Table 7: Performance Equations for Aggregate Innovation Output

	Model I INNOVATION			Model II R&D		
	TFP			TFP		
VARIABLES	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**
Aggregate Innovation Output	0.1740	0.0389	0.2956	0.2549	0.0515	0.1325
	(0.2563)	(0.0711)	(0.2001)	(0.2573)	(0.2896)	(0.3453)
	[0.2197]	[0.0579]	[0.2429]	[0.3766]	[0.4623]	[0.5426]
International competition indicator	0.1155**	0.0005	0.0331	0.2028	0.3266	-0.1511
	(0.0570)**	(0.0005)	(0.0754)	(0.2579)	(0.4269)	(0.5649)
	[0.0533]**	[0.0005]	[0.0697]	[0.2241]	[0.3476]	[0.5621]
Foreign capital indicator	0.0005	0.8456	0.0012**	0.0002	0.0002	0.0025
	(0.0004)	(0.0251)***	(0.0005)**	(0.0012)	(0.0016)	(0.0023)
	[0.0004]	[0.0229]***	[0.0005]***	[0.0011]	[0.0013]	[0.0020]
Initial TFP	0.9023	-0.0000	0.7642	0.8939	0.8252	0.8097
	(0.0232)***	(0.0000)	(0.0280)***	(0.0228)***	(0.0627)***	(0.0758)***
	[0.0175]***	[0.0000]	[0.0230]***	[0.0523]***	[0.0749]***	[0.0916]***
Age	-0.0000	0.0000	-0.0000	-0.0000	-0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Age2	0.0000	0.0000	0.0000	0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)*	(0.0000)	(0.0000)	(0.0000)
	[0.0000]	[0.0000]	[0.0000]*	[0.0000]	[0.0000]	[0.0000]
Size						
Medium	-0.0182	-0.0175	0.0114	-0.1229	-0.1264	0.0428
	(0.0224)	(0.0216)	(0.0236)	(0.0801)	(0.1064)	(0.1110)
	[0.0199]	[0.0224]	[0.0252]	[0.1001]	[0.1403]	[0.1471]
Large	-0.0279	-0.0471	-0.0324	-0.0886	-0.1041	-0.0545
	(0.0308)	(0.0532)	(0.0548)	(0.0775)	(0.1222)	(0.1146)
	[0.0275]	[0.0349]	[0.0410]	[0.0868]	[0.1135]	[0.1226]
Constant	-0.3648	0.4132	2.0914	0.9980***	1.4277***	1.8596***
	(0.2655)	(0.2374)*	(0.2294)***	(0.1597)***	(0.3212)***	(0.5611)***
	[0.6616]	[0.5718]	[0.4056]***	[0.5661]*	[0.6473]**	[0.7676]**
Observations	4636	4637	4638	377	377	377
R-squared	0.706	0.634	0.567	0.687	0.696	0.626

*** p<0.01, ** p<0.05, * p<0.1. All regressions include sector dummies. Robust standard errors in () and Bootstrap standard errors in [].

Table 7: Performance Equations for Aggregate Innovation Output (Continued)

	Model I INNOVATION			Model II R&D		
	Sales per worker			Sales per worker		
VARIABLES	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**
Aggregate Innovation Output	0.7849	6.1945	3.8188	0.8091	1.0380	0.2156
	(0.3731)**	(0.4210)***	(1.1023)***	(0.7827)	(0.8257)	(1.6930)
	[0.3979]**	[0.9236]***	[1.0682]***	[0.8155]	[0.8960]	[1.5124]
International competition indicator	0.6929	0.5828**	0.6381	0.4995	-1.1094	-0.8873
	(0.1672)***	(0.2774)**	(0.3201)*	(0.2992)	(1.1001)	(1.2633)
	[0.0944]***	[0.1927]***	[0.2699]**	[0.4690]	[1.7684]	[1.9142]
Foreign capital indicator	0.0063	0.0063	0.0021	0.0025	0.0052	-0.0023
	(0.0007)***	(0.0015)***	(0.0022)	(0.0037)	(0.0050)	(0.0118)
	[0.0007]***	[0.0014]***	[0.0024]	[0.0027]	[0.0050]	[0.0096]
Capital stock	0.1158	0.1813	0.1935	0.1584	0.1737	0.2231
	(0.0182)***	(0.0340)***	(0.0329)***	(0.1112)	(0.1201)	(0.1669)
	[0.0116]***	[0.0306]***	[0.0397]***	[0.0808]*	[0.0781]**	[0.1283]*
Human capital indicator	0.5549	0.7885	1.1169	0.7653	0.7468	0.5718
	(0.2288)**	(0.3018)**	(0.2528)***	(0.3064)**	(0.4116)*	(0.7215)
	[0.0976]***	[0.2082]***	[0.2903]***	[0.3539]**	[0.6294]	[0.8563]
age	-0.0000	-0.0000	0.0000	-0.0000	0.0001	0.0001
	(0.0000)***	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0001)
	[0.0000]***	[0.0000]	[0.0000]	[0.0000]	[0.0001]	[0.0001]
age2	0.0000	0.0000	-0.0000	0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Size						
Medium	0.1816	0.3451	0.4049***	0.3106	0.4155	0.2831
	(0.0412)***	(0.0572)***	(0.0697)***	(0.1123)**	(0.1878)**	(0.3205)
	[0.0352]***	[0.0627]***	[0.1153]***	[0.1909]	[0.2301]*	[0.4171]
Large	0.3182	0.3966	0.5902	0.1981	0.3828	0.4464
	(0.0849)***	(0.1145)***	(0.1459)***	(0.1451)	(0.2066)*	(0.4125)
	[0.0554]***	[0.1169]***	[0.1764]***	[0.1671]	[0.2830]	[0.4974]
Constant	7.8488	6.1945	4.4583	10.6105	9.7844	10.3757
	(0.2121)***	(0.4210)***	(0.5849)***	(0.8504)***	(1.4915)***	(1.4598)***
	[0.9352]***	[0.9236]***	[1.2462]***	[1.3167]***	[1.6179]***	[2.2584]***
Observations	4632	4632	4632	377	377	377
R-squared	0.397	0.178	0.123	0.531	0.380	0.306

*** p<0.01, ** p<0.05, * p<0.1. All regressions include sector dummies. Robust standard errors in () and Bootstrap standard errors in [].

7 Conclusions

The main objective of this paper is to establish a formal relationship between innovation and performance (productivity and sales) for the case of Colombian firms. We find that, as predicted by the literature, adaptation (innovation that results in goods and services new to the firm and to the domestic market) enhances firms' productivity and sales. In the same way, innovation in management and marketing boosts firms' productivity and sales. However, contrary to theoretical predictions, "true" innovation (that results in goods and services new to the international market) has a strong negative impact on TFP, although it largely increases sales when firms invest in R&D. Also, innovation in production processes also negatively influences firms' performance. When interpreting these results, it is important to keep in mind that in Colombia innovation is yet to play a central role in the national development strategy played by the government and the productive sector itself. Only recently, have policy makers taken necessary steps towards making innovation the basis for the competitiveness and productivity national agenda and the data analyzed here predates these policy changes. Hence, it remains for future research to study the relationship between innovation and productivity using more recent data currently not available.

We also study the factors behind the firms' decision to invest in innovation and the intensity of such investment. We find that large and medium firms innovate more intensely than small firms, as well as firms with greater market share, exporting firms, firms with foreign ownership, and capital-intensive firms. However, these firms' characteristics do not appear to encourage R&D investments. Additionally, human capital appears to be highly relevant for innovation and the greater the share of qualified managers and engineers, the larger the amount invested. We also find that public instruments are effective promoters of innovation but only some of them have an effect on the amount invested, such as competitiveness and productive development instruments. Similarly, the existence of formal protection methods is an important determinant of the decision to innovate and its intensity. The origin of innovation ideas matters for investing in innovation, and the strongest effect is observable when ideas come from external relationships (e.g. universities, consultants and information systems.

Finally, we estimate the returns to investment in innovation. We find that greater innovation efforts significantly increase the probability of obtaining any innovation output, except for innovation in management and marketing. Nonetheless, the impact of investing in R&D on obtaining innovation in goods and services is not significant, but it does influence innovation management and marketing. Additionally, larger firms are more prone to reach innovation outputs than smaller ones. We find that innovation ideas coming from inside the firms, from other firms, or from their relationships with universities, research centers and other external agents make easier the achievement of successful innovation in management and marketing. When investment is done specifically is R&D, except for specialized groups all sources of ideas have a significant impact in obtaining innovation output of all kinds.

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Annex 1: Literature review

Authors	The innovation input equation		The innovation output equation		The productivity equation		Methodology
	Dependent variable	Independent variables	Dependent variable	Independent variables	Dependent variable	Independent variables	
Crépon et al. (1998)	k	l,MS,d,δ,τ and S	n or t	k, l ,δ,τ and S	q	l,c,E,A and S	ALS
Lööf et al. (2001)	g(1) or k(2)	(1) l, exp,pa, NR&DE and A. (2) l,exp,pa, NR&DE,A, KII,CII,Firmesta, Obstacles,Information sources ,and Strategy	t	k, MR, and same variables that are using in the innovation input equation	Ln(Sales/l)	t and plus same variables using in the innovation output equation	Probit and Tobit to input equation, 3SLS to output inno. equa. and 2SLS to productivity e.
Griffith et al. (2005)	k	l, ln (exp/sales),δ,τ ,S,Obstacles,Information sources , Strategy and IM	PRI. PI t to firm t to the market.	k, and same variables that are using in the innovation input equation	Ln(Sales/l)	(PRI. PI t to firm t to the market, and same variables that are using in the innovation output equation	3SLS
Masso & Vahter	g(1) or k(2)	(1) l, S, exp, Sub, F. Protection (2) S, exp, Sub, F. Protection, Obstacles,Information sources ,and Strategy	PRI PI	k and same variables that are using in the innovation input equation	Ln(Sales/l) Ln(value added/l)	PRI,PI,l(t-2),c and OIE(t-2)	Probit and Tobit to input equation, 3SLS to output inno. equa. and 2SLS to productivity e.
Van Leewen & Klomp	k IIN	l,MS,d,δ,τ ,S, Cash Flow, Sub	t	l,MS,d,δ,τ and S	Ln(Revenue/l)(1) Ln(value added/l)(2)	(1) t, c, l, Dem. Shift, Price Elasticity of demand , Inv. Mark-up and Return to scale (2)t,c,l and return to scale	Probit and Tobit to input equation, 3SLS to output inno. equa. and 2SLS to productivity e.
Jefferson et al.	k(t-1)	l(t-1), (1/d)(t-2), S, k(t-2)	t	k(t-1), k(t-1)*l, age , S	TPF Profitability	t, l c, S	IV
Benavente (2006)	k	l,MS,d,δ,τ and S	t	k, l ,δ,τ and S	q	l,c,E,A and S	ALS with selectivity and simultaneity

Duguet	-	-	1) Incremental Innovation (INC) or Radical innovation (RAD). 2) 3 possibles ordered values (Non innovative , INC and RAD)	Sales, MS, δ,τ , Group R&D, n, Rights and Licenses	The change of TFP	TFP(-1), (1) or (2)	Separate logit or Ordered logit to the innovation e, and GMM to productivity e.
Gu & Tang.	-	-	Latent variable representing innovation=e	k, n, Skill labor and M&E per worker	Labor productivity	year, capacity utilization, employment share of large firms, K/L, e(t-1), …, e(t-3)	Pool estimation

Keys

k	research(R&D) capital per employee	
l	log of employee	
ms	log of average market share	
d	log diversification	
δ	demand pull dummies	
τ	technology push dummies	
S	industry dummies	
n	patents number	
t	percentage share of firm new sales	
q	log-value added per employee	
c	log of physical capital per employee	
A	share of administrators in the total of employee	
E	share of engineers in the total of employee	
exp	export intensity	
pa	Patents applications	
NR&DE	non R&D- engineers	
KII	Knowledge-intensive industry	
CII	Capital intensive industry	
Firm estab.	Firm was established	
h	human capital	
LSF	Lack appropriate sources of finance	obstacles
OR	Organizational rigidities	strategy
LQP	Lack of qualified personnel.	Sources

		information
IP	Improving products	
ONM	Opening new markets	
EPR	Extending product range	
RP	Replacing products being phased out	
RLC	Reducing labor cost	
IPF	Improving production flexibility	
ICH	innovation cost high	
LCR	Lack of consumers responsive	
FRS	Fulling regulation standards	
LIT	lack of information technology	
SE	Sources within the enterprise	
COS	Customers	
COM	Competitors	
CIN	Computer-based information networks	
FEX	fair, exhibitions	
UNI	Universities	
MR	The inverted Mill`s ratio	
PRI	Process innovation	
PI	Product Innovation	
OIE	Organizational innovation export	
IIN	Innovation capital per employee	

Annex 2: Definition of Variables

Innovation engagement: Dummy variable which takes the value 1 if the firm reports innovation activities during 2004.

Innovation Intensity: Total innovation expenditure per employee in 2004 (in logs)

Innovation in Good or Services: Dummy variable which takes the value 1 if the firm reports having introduced new or significantly improved goods or services during 2004 (new production process for a complementary or main production line).

Innovation in Production Processes: Dummy variable which takes the value 1 if the firm reports having introduced new or significantly improved production processes during 2004 (new to the firm, new to the national market or new to the international market).

Innovation in Management and Marketing Procedures: Dummy variable which takes the value 1 if the firm reports having introduced new or significantly improved managerial or marketing procedures during 2004 (new to the firm, new to the national market or new to the international market).

Labor productivity: Sales per employee in 2004, 2005 and 2006 (in logs).

Capital Stock: Capital stock in tangible goods in 2004, per employee (in logs).

Public policy: Dummy variable which takes the value 1 if the firm received public funding for innovation projects during 2003-2004. There are five policy instruments.

<u>Sources of Innovation</u>**:**

- *Internal sources within the firm*: Dummy variable which takes the value 1 if the information from internal sources within the enterprise was of high importance during 2004.

- *Others enterprises as source of information*: Dummy variable which takes the value 1 if the information that comes from other firms was of high importance during 2004 (parent company, competitors, suppliers).

- *Specialized groups as source of information*: Dummy variable which takes the value 1 if the information that comes from specialized groups was of high importance during 2004 (e.g. Chambers of Commerce, Associations)

- *External relationships as sources of innovation*: Dummy variable which takes the value 1 if the information that comes from external relationships was of high importance during 2004 (e.g. Universities).

Formal Protection firm: Dummy variable which takes the value 1 if the firm used patterns, trademarks, or copyright to protect inventions or innovations during 2004.

Formal Protection industry: the total patterns of industry minus firm´s patterns between 1996 and 2004.

Export intensity: Percentage of export sales.

Foreign capital indicator: Percentage of foreign capital.

Size: Set of size dummy variables according to the firm's number of employees in 2004. These are categorized in 2 groups: medium and large.

Industry: Set of industry dummies according to the ISIC classification.