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Innovation, R&D Investment and Productivity in Colombian Firms

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Abstract[1]

This paper attempts to establish a formal relationship between innovation and productivity using Colombian firm-level data. It is found that the production of goods and services new to the firm and to the domestic market enhances firms' sales per worker, and innovation that results in introducing new goods and services to the international market boosts both sales and Total Factor Productivity (TFP). Innovation in processes likewise improves firms' productivity and sales. Finally, innovation in marketing and management increases sales per worker and enhances TFP when investment is made in R&D. The paper also studies the factors behind firms' decision to invest in innovation, the intensity of such investment and the returns to investment in innovation.

JEL classifications: 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 of productivity growth. However, the evidence is weak when establishing this relationship outside the developed world. Masso and Vaher (2008) looked at the link between innovation and productivity using Estonian firm-level data and found that, depending on 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 represents 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 firm size is positively correlated with the decision to invest but negatively correlated with innovation intensity. The author explains his results based on the fact that larger firms have advantages inherent to their size that make 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 to improve their equipment for innovation. Alvarado also finds that firms that receive foreign investment and 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.

More recently Langebaek and Vásquez (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 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 (TFP).

Second, we take advantage of the availability of a relatively long panel of firms, which allows 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 endogenous nature of the model. Unfortunately, as the innovation dataset is only available for one year,[2] 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 science, technology and innovation policy in Colombia. Section 3 briefly describes the evolution of the manufacturing sector during the period 1998-2006. 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

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 overall science, technology and innovation (STI) policy all round.

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

The development of STI policy in Colombia can be divided into four stages: the first from 1968[3] until 1989, the second from 1990 until 1999, the third from 2000 until 2008 and the current stage, which begin in 2009. In what follows, we briefly describe each of the stages, emphasizing the last two.

The beginning of the first stage of the Colombian STI policy is 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 doctoral programs, were created. Also, institutes dedicated to R&D were founded, some of which are still functioning.[4] Finally, IDB Loan 1: ICFES-Colciencias was disbursed and became the main instrument for modernizing 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 well-defined and coherent policy. In 1988, the Mission for Science and Technology was organized with the objective of 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 on the results from the Mission, defined national science and technology policy. 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 sector and academia. The SNCT was headed by the CNCT, the councils for national programs,

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[3] Some authors consider the first stage to the period prior to 1968, starting in 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)

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 the 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 created to increase 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, the Superintendency 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 Law 6 of 1992 giving tax incentives related to STA, and of Law 344 of 1996 ordering SENA to allocate 20 percent 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 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, Conpes Document 3080 defined national science and technology policy for 2000 and 2002, and Conpes Document 3179 of 2002 established support for doctoral education in 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

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

in the 2002-2006 PND (Law 812 of 2003), and the 2006-2010 PND establishes STI as one of its main dimensions. In the latter 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 for institutional and legal changes and a commitment to invest more in this sector.[6] Other government documents setting out medium and long-term STI 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 for STI investment have increased considerably. For example, the Law 812 of 2003 dictated that SENA should allocate one fourth of the 20 percent 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 2008 and 2009, Colciencias' budget was increased in real terms by 42 percent and 34 percent, 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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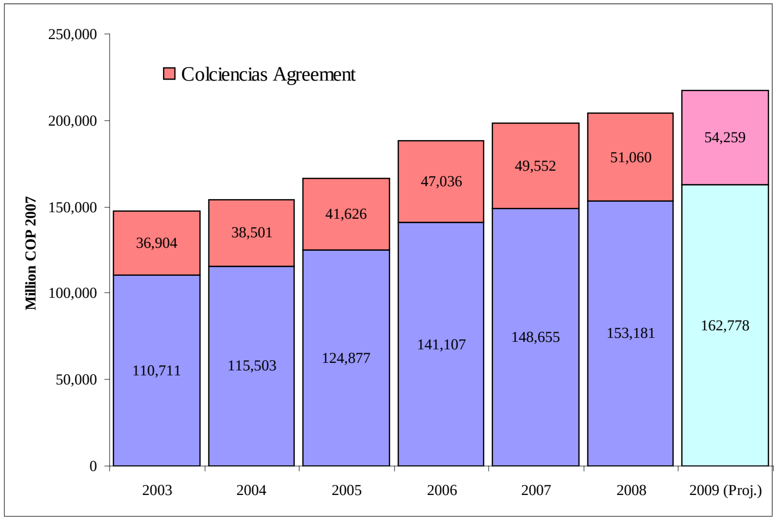
[6] The 2006-2010 PND sets the strengthening of the STI sector as a key tool for improving employment, security, and poverty and health problems, and it established eight programmatic strategies: i) increase knowledge generation; ii) promote innovation and productive development; iii) promote social STI appropriation; iv) increase and strengthen human capabilities for STI; v) reinforce SNCTI's institutionality; vi) reinforce infrastructure and information systems for STI; vii) promote regional integration; and viii) strengthen STI's international projection.

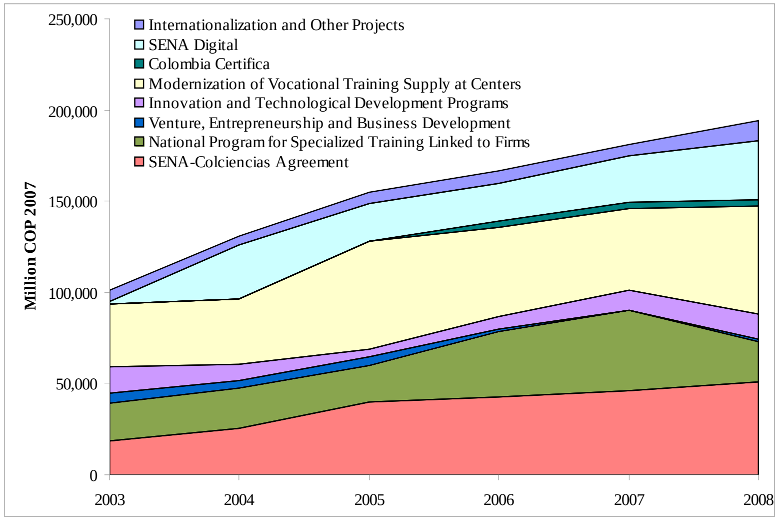
[7] Since 2002, SENA has financed 7,592 projects worth $991,415 pesos under its umbrella of innovation and technological development (ITD) programs. Among these, it merits mentioning the *Innovación y Desarrollo Tecnológico con el Medio Externo a la Entidad* (ITD with the Environment External to the 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 million 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 non-refundable seed capital for their projects provided these are applications of their studies. Currently, 1,657 projects worth $94.711 million pesos have been approved through six 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 in 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

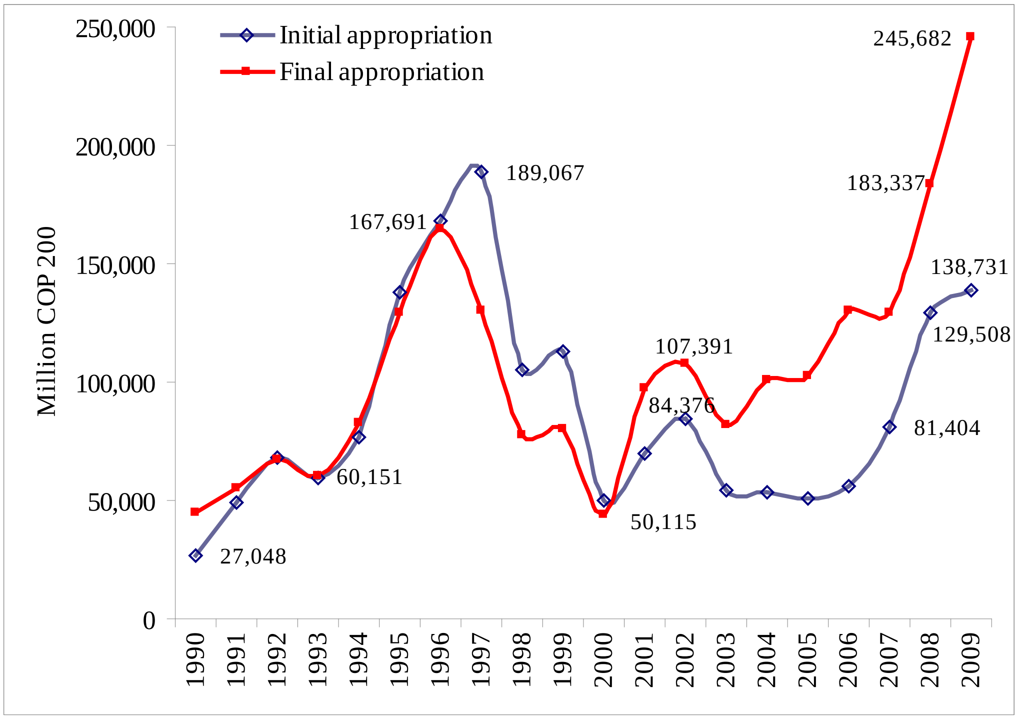


Panel B. ITD-Related Programs



Notes: i) Colciencias' Agreements account for one fourth of the 20 percent 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: Authors' calculations based on SENA reports.

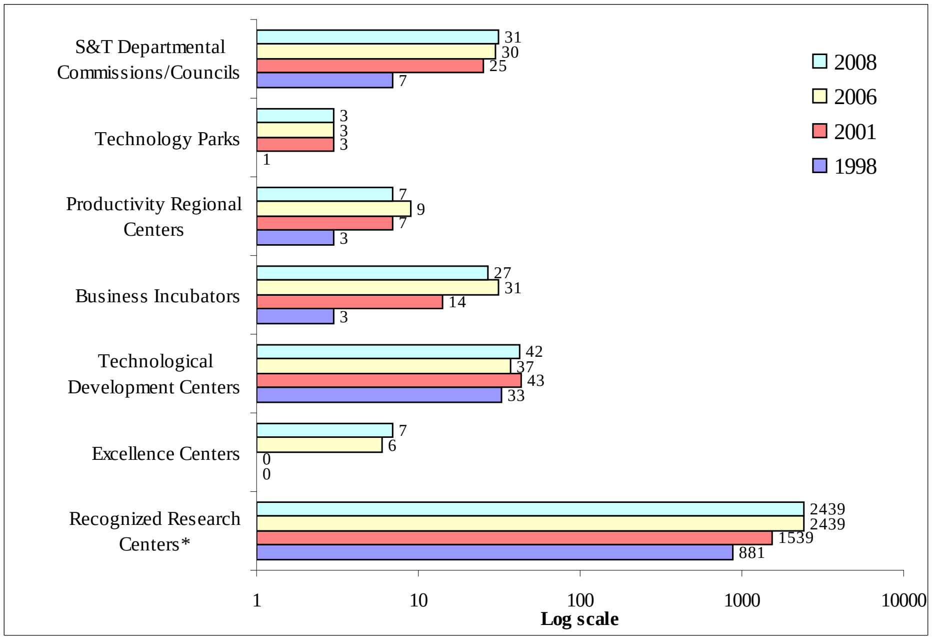
Figure 2. Colciencias Budget



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.

Moreover, the number of STI-supporting institutions has increased significantly in the last 10n years. Up to 2008, following a process based on the promotion and preservation of quality, Colciencias has named 2,439 recognized research centers, 1,558 more than in 1998. Since 2006, seven Excellence Centers have been created with a commitment to working in continuous contact with international research groups, promoting education at the master and doctoral 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, as shown in Figure 3 below.

Figure 3. STI Supporting Institutions



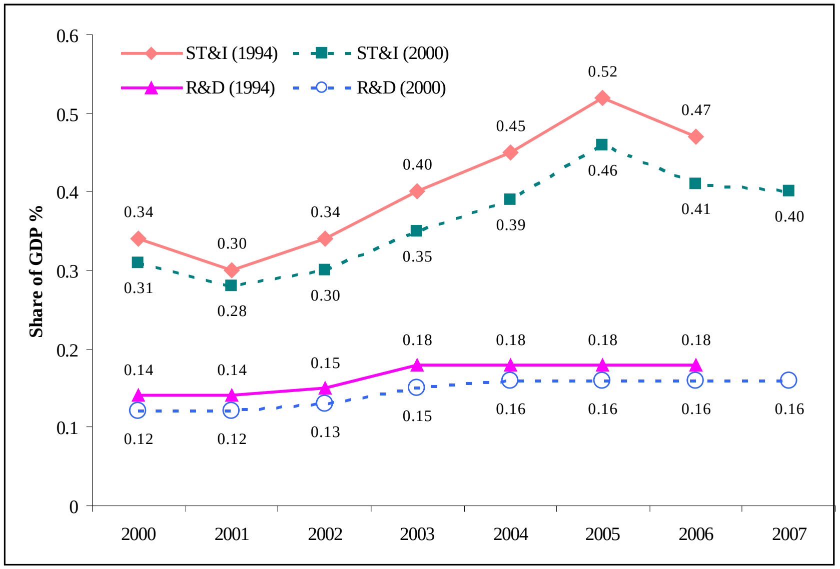
*Since 2002 research centers are categorized between registered and recognized; the latter having concrete results and being voluntarily submitted to a Colciencias classification. *Source:* Colciencias.

Furthermore, in 2004 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 percent and 0.12 percent of GDP, respectively. In 2007, these shares increased to 0.40 percent for STIA and 0.16 percent for R&D, as shown in Panel A of Figure 4. These shares are around one-fifth to one-half the investment made by neighboring countries such as Brazil, and below the regional average, as shown in Panel B of Figure 4.

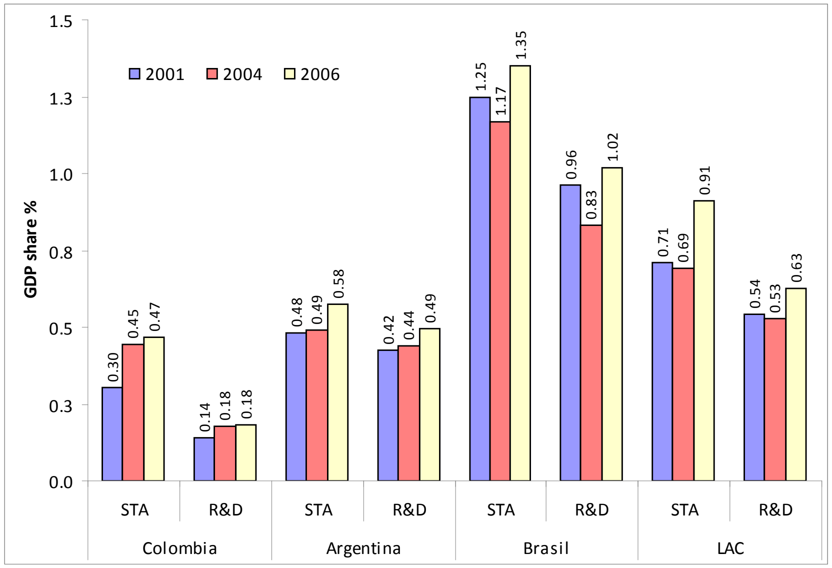
Figure 4. Size of Science, Technology and R&D Activities

Panel A



Source: OCyT.

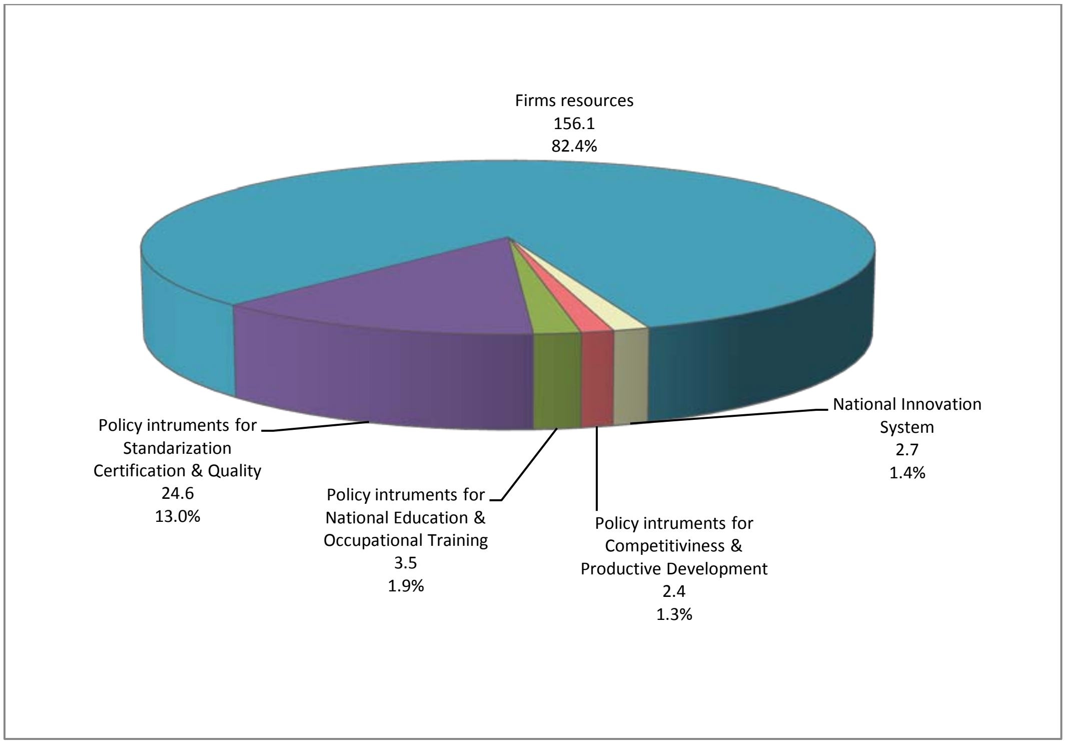
Panel B



Source: RICYT.

Moreover, according to EDIT II, the SNI accounts for only 1.4 percent (2.7 billion 2003 COP) of the pool of financing instruments used by firms.[8] Likewise, policy instruments for competitiveness and productive development account for 1.3 percent (2.4 billion 2003 COP), instruments for occupational training account for 1.9 percent (3.5 billion 2003 COP) and instruments for standardization, certification and quality account for 13 percent (24.6 billion 2003 COP). In fact, manufacturing firms finance 82.4 percent (156.1 billion) of their innovation-related activities using their own resources, as shown in Figure 5.

Figure 5. Instruments for Innovation Employed by Manufacturing Firms in 2004
(Billions of 2003 COP)



Source: Authors' calculations based on EDIT II.

[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 Sálazar (2007).

Low public investment in STIA is tied to the fact that the manufacturing sector barely uses the public instruments available for promoting and financing innovation-related activities. This may be a reflection of institutionally weak STIA policy, which leads to low expectations in terms of innovation output and its effect on productivity. With this in mind, the government has recently taken 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, Francisco José de Caldas) among other related actions. Hence, one may claim that 2009, by coordinating past efforts, marks the beginning of a new and 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) database.

In general terms, the manufacturing sector was strongly hit by the crisis of the end of the 1990s (in 1999 the Colombian economy contracted by 4.5 percent), and began a steady recovery in 2000. Indeed, industrial production declined by around 6 percent in real terms in 1999, but grew 10 percent in 2000 and continued to increase thereafter. It exhibited an average real growth rate of 7 percent during the period 2000-2006, reaching a peak of 14 percent in 2006. Sales also increased by an annual average of 9 percent during the period, after having fallen 9.4 percent 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 percent in 2000-2006.

Table 1. Manufacturing Sector, Main Statistics (2004 COP, Million)

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Number of establishments	7,861	7,441	7,246	6,960	6,881	7,230	7,249	7,524	7,369
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	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 percent on average in 2000-2006. Figure 6 also shows that labor productivity is positively related to the size of the firm, and it has particularly increased 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[9] has exhibited the same increasing pace and shows similar patterns regarding firms' size. Large firms have a TFP greater than that of medium and small firms. All the three groups show a drop in 1999, which reflects the effects of the worst economic crisis in Colombian recent history, and an upturn from 2000 onwards. Nevertheless, TPG grew at a notably slow rate after the recovery, with average growth of less than 1 percent during the period 2000-2006 (see Figure 7).

[9] It corresponds to the average of firms' TFP.

Figure 6. Labor Productivity
(Sales per Worker, 2004 constant COP)

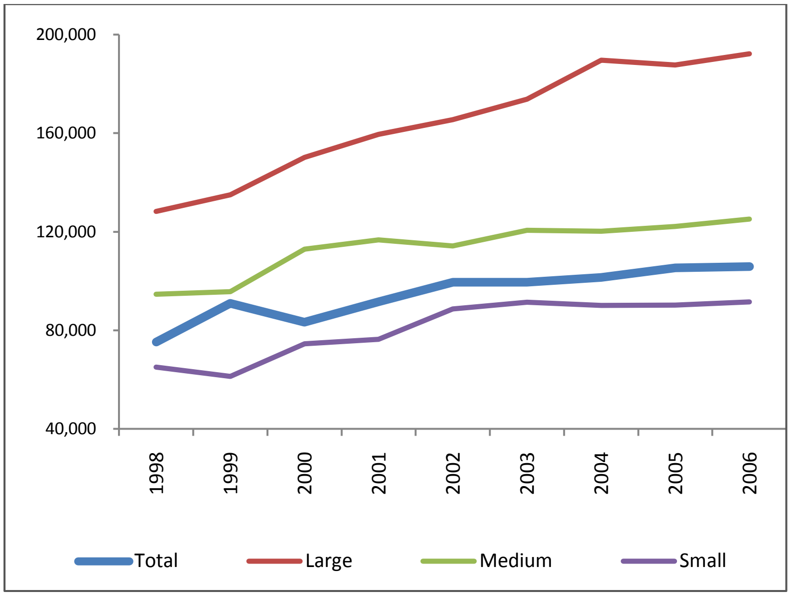
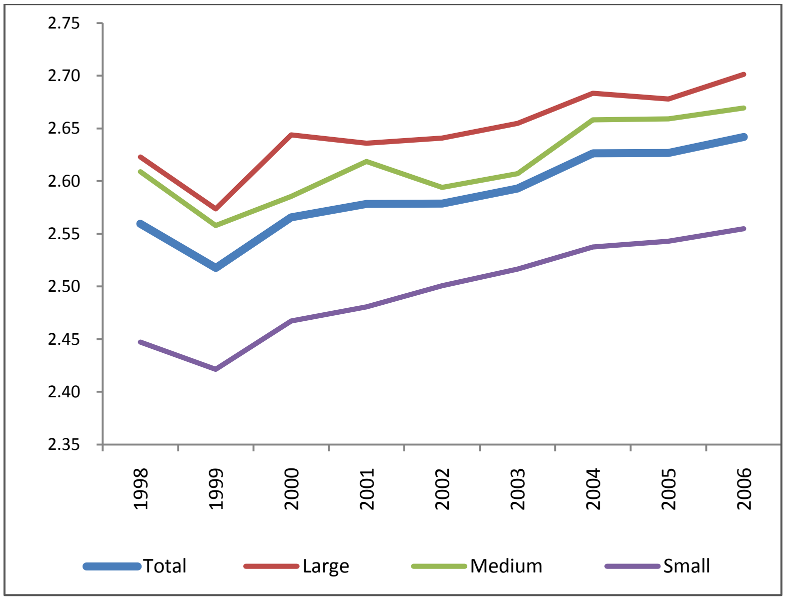


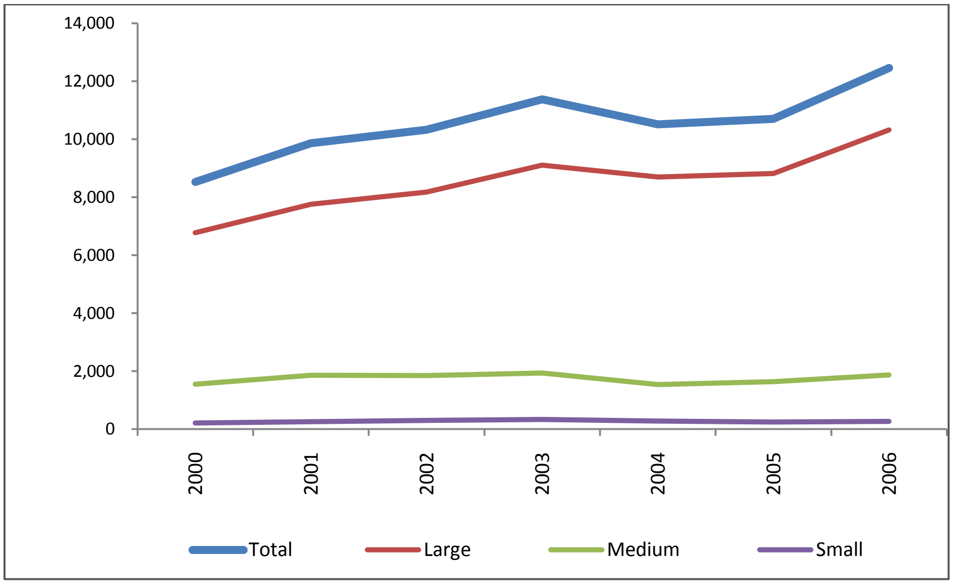
Figure 7. Total Factor Productivity
Log (TFP)



Source: EAM, DANE and authors' calculations.

Exports in the manufacturing represent only around 11 percent of industrial production. The share of exports increased slightly in 2001-2003 (around 12.5 percent), but subsequently declined to 10 percent. However, exports grew during 2000-2006 (around 7 percent in average) especially in large firms, which can be positively related to TFP growth during the same period (Figure 8).

Figure 8. Exports by Manufacturing Firms
2004 constant COP, Million



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 refined by Crépon, Duget and Mairesse (1998), known in the literature as the CDM model.[10] This model has been the base of recent research on the topic, and it 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:

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[10] Crépon, Duguet and Mairesse (1998) included a third equation intended to correct for selectivity and simultaneity issues present in the Pakes and Griliches (1984) model.

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

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

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

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

Equation (1) describes the decision of firms to invest in innovation 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. Equation (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.[11] As earlier research has focused its analysis on R&D activities, we likewise 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. Equation (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, Duguet and Mairesse, 1998) and as a 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 goods 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 in goods and services occurs when production is new to the international market.

[11] 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.

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, Huergo and Mairesse, 2006; Masso and Vahter 2008; and Lööf and Heshmati 2006). However, some authors (Duguet, 2006, and Jefferson et al. 2006) have used measures of total factor productivity (TFP). In the present paper, we explore the effect of innovation output on two different measures of firm performance: log of sales per employee and 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.[12]

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 in 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[13] and attempt to model more explicitly the endogenous nature of the model.

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[12] 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.
[13] Masso and Vahter (2008) estimate this effect.

Table 2. Vectors of Explanatory Variables

Equation		Explanatory Variables
Eq. (1)	=	(public financing for innovation indicator, use of innovation policy indicators, formal protection to knowledge indicator, human capital indicators (highly qualified and qualified employees, research department indicator), foreign capital ownership indicator, international competition indicator, firm's capital stock, market share, firm's size indicators, firm's age, firm's age squared, industry dummies)
Eq. (2)	=	(public financing for innovation indicator, use of innovation policy indicators, formal protection to knowledge indicator, human capital indicators (highly qualified and qualified employees, research department indicator), sources of ideas for innovation, international competition indicator, foreign capital ownership indicator, firm's capital stock, market share, firm's age, firm's age squared, industry dummies)
Eq. (3)	=	(innovation intensity (predicted), human capital quality indicators (highly qualified and qualified employees, research department indicator), sources of ideas for innovation, international competition indicator, foreign capital ownership indicator, firm's capital stock, firm's size indicators, firm's age, firm's age squared, industry dummies)
Eq. (4)	=	(innovation output (predicted), human capital quality indicator (highly qualified and qualified employees), foreign capital ownership indicator, international competition indicator, firm's capital stock[14], firm's size indicators, firm's age, firm's age squared, industry dummies)

Finally, in order to estimate the model we follow an approach similar to that used in Griffith, Huergo and Mairesse (2006), Lööf and Heshmati (2006) and Duguet (2006). We estimate equations (1) and (2) of the model 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.

Although the EDIT II is 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 firm 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

[14] We will exclude physical capital when using TFP as dependent variable. We do not exclude the human capital indicators since these are measures of quality that do not enter the estimation of TFP.

[15] EDIT II is a rider of the EAM 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 II) as well as when considering the broader notion of innovation investment (Model I). 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, equation (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, equation (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.

The Development and Technological Innovation Industrial Survey (EDIT II) constitutes a fundamental tool for characterizing the innovation and technological development activities of manufacturing firms in Colombia.[17] This survey was conducted in selected years (1996, 2005 and 2007) among all industrial firms according to the directory of establishments in the Annual

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

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 obtain information related to the innovation behavior of firms and also comprehensive information regarding 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 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 3. The second part enquires about technological development activities and objectives of innovation. Lastly, the survey gathers information regarding the financial sources of technological development and innovation activities, public innovation policies and formal protection of 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 projects; 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. In a different chapter the survey collects information about objectives, outputs and sources of ideas for technological innovation during 2003 and 2004. In particular, firms report information about the importance of their innovation objectives, the state of 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, such as whether the source is internal or external to firm. This information is relevant for our empirical analysis since similar information has been also used in the literature Lööf and Heshmati (2006) and Masso and Vahter (2008). Finally, there is a chapter that gathers information on firms' personnel per area or department, according to the type of appointment (permanent, temporary), gender, education level and origin. This information is relevant as well because it allows us to calculate very accurately firms' human capital with a great deal of accuracy. 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 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, there is a chapter dedicated to formal protection of innovation. It collects information regarding patent applications, industrial design registration, trademark registration, copyright registration and new software registration.

The Annual Manufacturing Survey (EAM) 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. This gives the EAM census-like properties. This sample corresponds to

[18] Metropolitan areas and sections of the country.

industrial directories reported by the guilds and updated every year by micro-surveys to detect the appearance of new units of analysis.

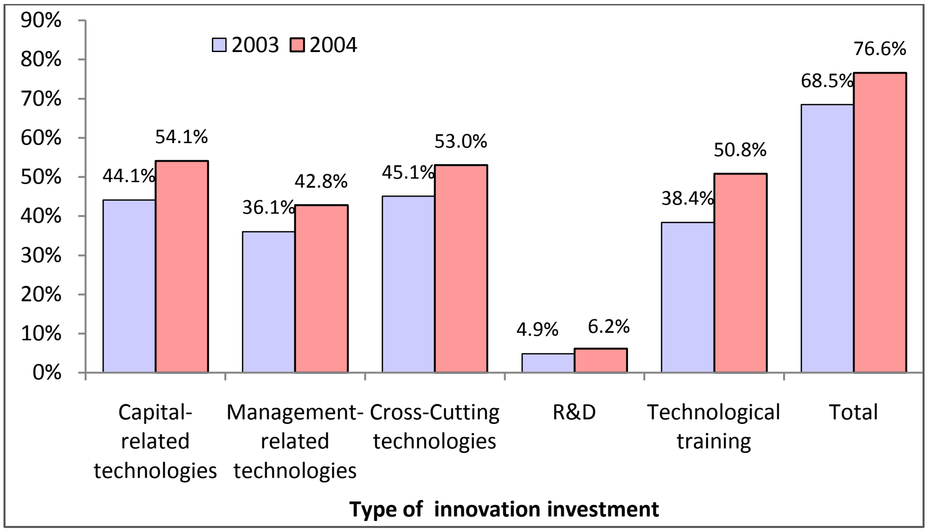
The basic concepts of this survey are the following: gross production, intermediate consumption and value added. Gross production includes products and sub-products, products in process, and rental of goods, among others. Intermediate consumption includes consumption of raw materials and packaging materials (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 number of employees in the manufacturing process. The total number of employees 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.

5.2 Data Descriptive Analysis

In this section we present descriptive statistics of the main variables of the model. 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 percent of the firms reported having invested in some type of innovation in 2004, up from 69 percent 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, in which only 6 percent of firms (382 firms) reported having invested.

[19] It refers to those assets that are not intended for sale.

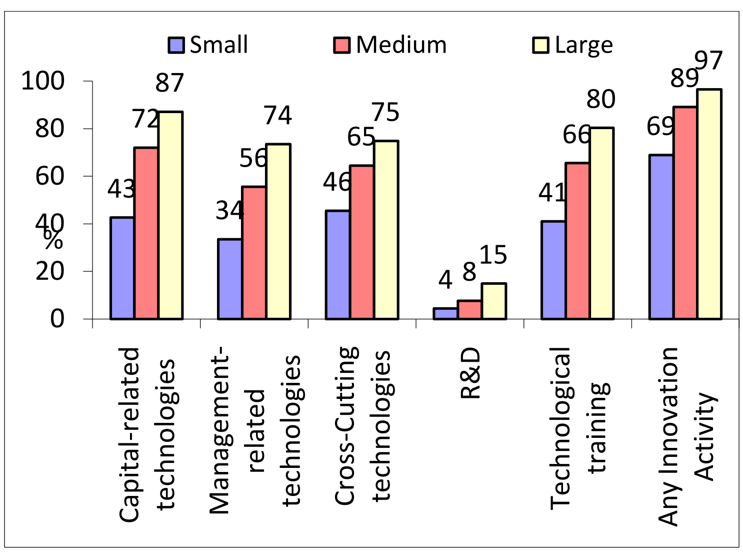
Figure 9. Share of Firms Investing in Innovation



Source: Authors' calculations based on EDIT II.

Figure 10 shows the share of firms that invested in each type of innovation input by size, and it is observed that innovation investment increases with firm size. For example, while only 43 percent of the smallest firms invest in capital-related technologies, 87 percent of the largest firms invest in those technologies. This pattern is even more marked in the case of investment in R&D: only 4 percent of the smallest firms invest in R&D compared to 15 percent of the largest firms.

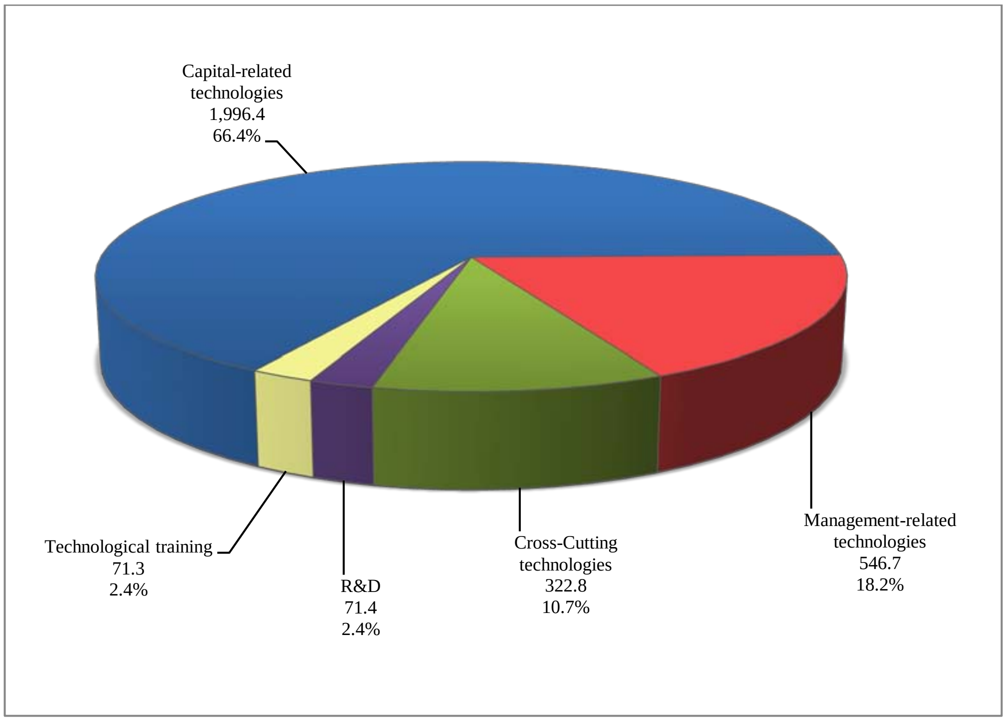
Figure 10. Share of Firms Investing in Innovation by Size



Source: Authors' calculations based on EDIT II.

Next we present the dependent variable of our second equation, innovation intensity, meaning the amount invested by firms in innovation. Figure 11 shows the distribution of innovation investment by type and the amount invested in 2004 (at 2003 prices). 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 percent), then to management-related technologies (18 percent) and cross-cutting technologies (11 percent). Note that investment in technological training and R&D amount to only 4.7 percent, which can be considered a low amount if the country were to boost innovation output and productivity in the future.

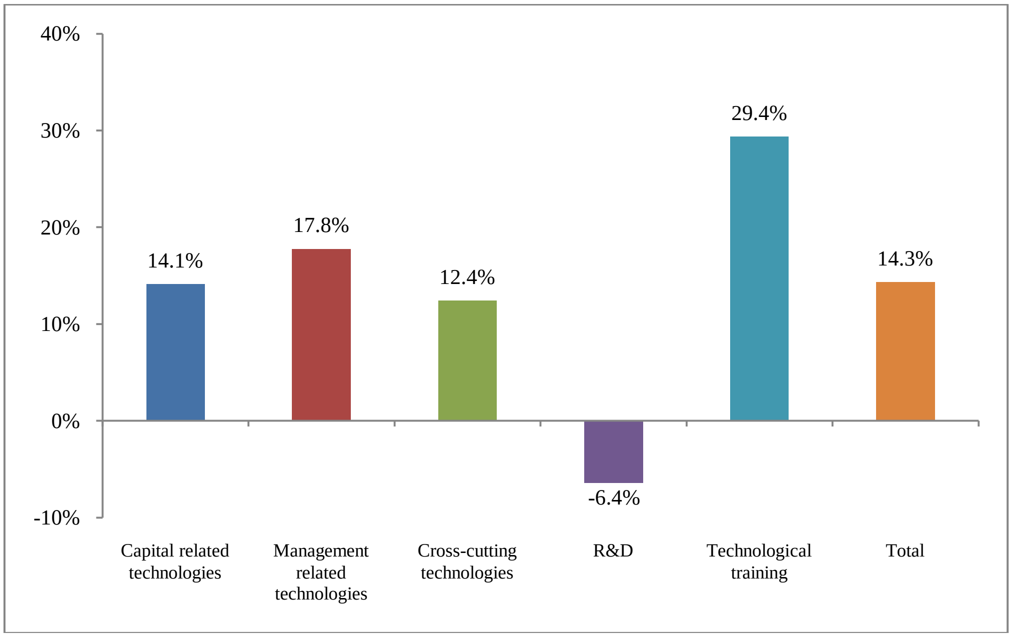
Figure 11. Distribution of Innovation Intensity by Type, 2004
2003 COP, Million



Source: EDIT II (2004).

Figure 12 illustrates the percentage change in innovation input between 2003 and 2004. In total, firms invested $3,009 million pesos in 2004, up from $2,630 million, representing a 14 percent increase in real terms.[20] This change, however, was not uniform across types: investment in technological training increased by 29 percent, while investment in R&D decreased by 6.4 percent. On the other hand, investment in managerial-related technologies, in capital-related and in cross-cutting technologies show increases of 17.8 percent, 14.1 and 12.4 percent, respectively.

Figure 12. Change in Innovation Intensity by Type, 2003-2004



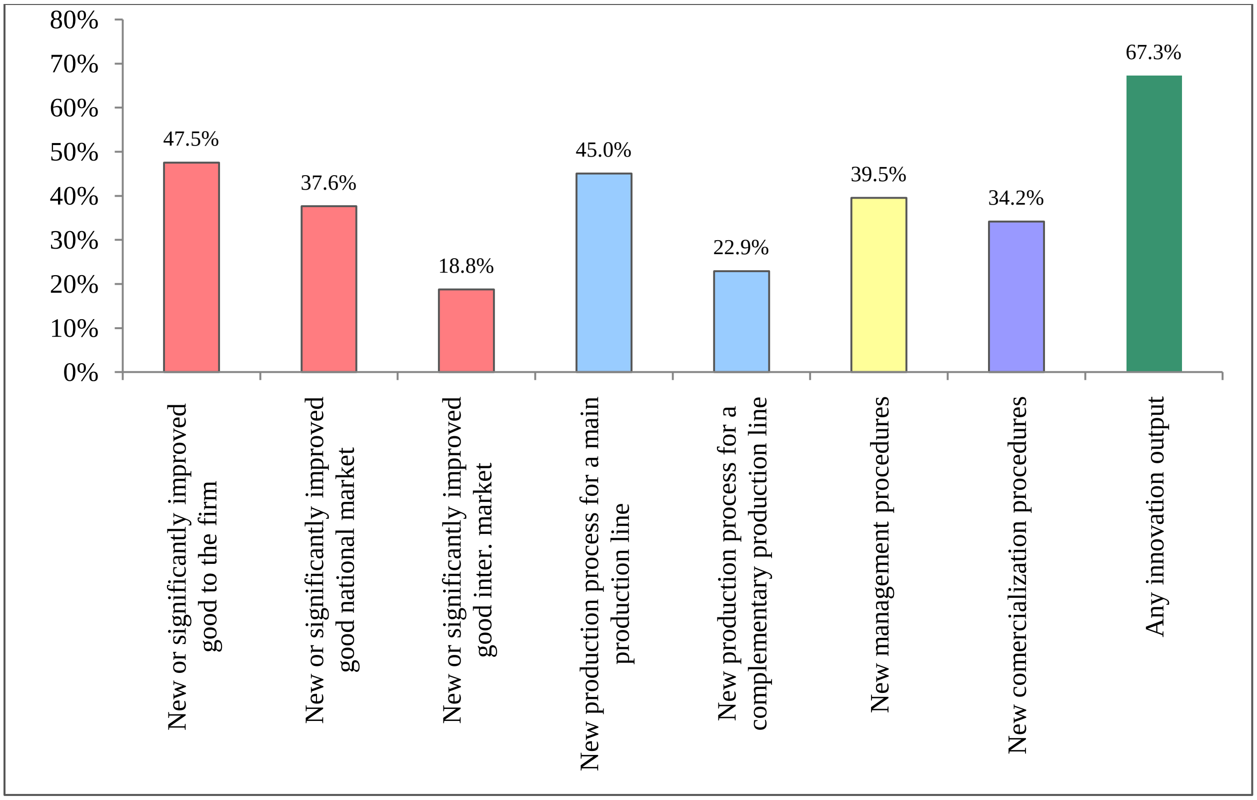
Source: EDIT II.

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 shown in the figure, the number of firms actually innovating is not large. In terms of product innovation, about one fifth of the firms report obtaining good and services new or significantly improved to the international market. This compares with the higher proportion of firms reporting production of goods and services new or significantly improved to the national market or to the firm itself (40 percent and 50 percent, respectively), which we consider to be adaptation as it corresponds to imitation of existing products in the international market. One may expect the effect of actual innovation on productivity to be different than that of just adaptation. In our empirical work we test this hypothesis.

[20] Manufacturing firms invested $3,130 million pesos in 2004 up from $2,630 million, a 19 percent increase in nominal terms.

Looking at innovation in the production process, we observe that there are more firms with innovative output in the process of the main production line than in the complementary production line. Finally, looking at the last two columns in Figure 13 one observes that the share of firms obtaining innovative output in the management and commercialization procedures is around 40 percent and 34 percent, respectively.

Figure 13. Innovation Output by Type



Source: Authors' calculations based on EDIT II.

6 Empirical Results

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

Table 3. Descriptive Statistics

VARIABLE	TOTAL				INNOVATORS				NON INNOVATORS			
	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
Inicial ltfp	7.00	0.85	-1.60	12.95	6.94	0.87	-2.65	13.00	6.84	0.84	-0.11	13.00
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	10.0	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	7,434	4,471	11	34,162	7,297	434	11	34,162	7,122	3,967	106	33,900
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
Human capital indicator												
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	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	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					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Intenal sources	0.81	0.39	0.00	1.00	0.79	0.40	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	0.00	0.00	0.00	0.00	0.03	0.18	0.00	1.00
External relationships	0.32	0.47	0.00	1.00	0.30	0.45	0.00	1.00	0.08	0.27	0.00	1.00
Number of observations	4,210				3,822				388			

Before we present the results, it should be noted that 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 innovation 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 innovation investment decisions of firms (equation (1)), and the amount they invest in such activities conditional on having decided to invest, that is innovation intensity (equation (2)). Both equations include the same explanatory variables except for the set of variables indicating sources of ideas for innovation, which is only included in the innovation intensity equation, and size dummy variables which are only included in the decision to innovate since innovation intensity is defined in terms of employment size. The numbers reported in the table correspond to marginal effects, which have been calculated following Vance (2006).

We find that firms' size is positively related to the decision to innovate: large and medium firms innovate more than small firms. Regarding the exporting indicator (international competition) we find a positive relationship with total innovation. Note that 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, endogenous growth models (e.g., Grossman and Helpman, 1991) predict that there is also a reverse effect since exports may themselves cause innovation activities.[21] 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. We do not find the same significant and positive relationship in the case of R&D, however.

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 relationship between innovation and foreign-capital ownership is quite common in the empirical literature based on

[21] 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 and Wößmann (2006).

the positive impacts of Foreign Direct Investment, and is explained by different factors: firms can 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 firms do not invest more in R&D; in fact, they are less likely to invest in R&D. This may 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 likely to innovate and spend larger amounts in innovation efforts. Nevertheless, we also find that capital-intensive firms do not show a greater propensity to invest in R&D, although they do invest larger amounts.

Human capital appears to be relevant for innovation. Firms with highly qualified workers are more likely to invest in R&D and show greater innovation and R&D intensity. More importantly, firms that have R&D departments are both more likely to invest in innovation and R&D and do so with greater intensity.

With regards to the sources of ideas for innovation, 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 (e.g., Chambers of Commerce) appears to be negative. In the case of R&D none of the sources appear to affect innovation activities.

The use of policy instruments for innovation increases the probability that firms decide to invest in innovation but does not increase the size of the investments.[22] An important result is that none of the public policy instruments influence the amounts invested in R&D. We do find, however, that the use of public financing increases the likelihood of making investment in innovation-related activities including R&D, and it is positively related with the investments' size.

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[22] In other specifications we found that 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 access to other firm-related instruments also have a significant effect. Interestingly, we find that the impact of public policy instruments is much less evident in the amount invested in innovation, except for the access to instruments associated with competitiveness and productive development and, to a lesser degree, training and educational programs.

Finally, the formal protection of knowledge creation (e.g., patents and utility models requested) increases the probability of investing in innovation activities and R&D as well as the amount invested in the latter.

Table 4. Selection and Innovation Equations

VARIABLES	Model I Decision to innovate (i)	Model I Innovation intensity (ii)	Model II Decision to invest in R&D (i)	Model II R&D intensity (ii)
Innovation-related Variables				
Public Financing for Innovation	1.4413***	0.7151***	0.4289***	0.8468***
	(0.164)	(0.071)	(0.083)	(0.256)
Use of Public Policy Innovation Instruments	1.6298***	0.0439	0.0736	0.3879
	(0.402)	(0.107)	(0.158)	(0.321)
Formal Protection to Knowledge Creation	0.5539***	0.1136	0.5584***	1.1104***
	(0.168)	(0.089)	(0.181)	(0.213)
Human Capital Indicators				
High Qualified Workers	0.2780	1.9575***	0.4169**	3.8551***
	(0.249)	(0.370)	(0.184)	(0.593)
Qualified Workers	0.0855	0.7035***	0.2721	1.0091**
	(0.180)	(0.116)	(0.182)	(0.400)
R&D Department	0.3356***	0.1649***	0.4315***	0.4283*
	(0.066)	(0.056)	(0.091)	(0.227)
Sources for Ideas				
Intenal sources		0.5595***		-0.1606
		(0.074)		(0.273)
Other firms sources		0.1827***		-0.1193
		(0.066)		(0.127)
Specialized groups		-0.1845**		0.0697
		(0.073)		(0.138)
External relationships		0.4601***		0.1629
		(0.054)		(0.196)
Firm Characteristics				
International Competition	0.3205***	0.1585***	0.0903	0.0925
	(0.059)	(0.061)	(0.086)	(0.141)
Foreign Capital Indicator	0.0890	0.4996***	-0.1440**	-0.2857
	(0.105)	(0.088)	(0.068)	(0.378)
Capital Stock	0.0382***	0.1039***	0.0171	0.0905***
	(0.009)	(0.018)	(0.012)	(0.029)
Market Share	0.4336	1.9341***	0.2481	0.4826
	(0.784)	(0.541)	(0.538)	(1.193)
Age				
Age	-0.0012***	-0.0013***	0.0007	-0.0014
	(0.000)	(0.000)	(0.001)	(0.002)
Age squared	0.0000***	0.0000**	-0.0000	0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
Size				
Medium (51-200 employees)	0.5828***		0.1103**	
	(0.071)		(0.048)	
Large (200+ employees)	1.0179***		0.4239***	
	(0.127)		(0.121)	
Constant	0.0571	3.4813***	-0.7252***	1.5881*
	(0.117)	(0.288)	(0.191)	(0.825)
Rho		-0.2440		0.7454
		(0.1053)		(0.1202)
Lambda (Inverse Mills Ratio)		-0.3959		1,308
		(0.1783)		(0.3954)
Wald Test of independent eq. (rho=0) $\chi 2(1)$		4.95		12.65
p-value		0.0261		0.0004
Total Observations		5934		5934
Censored Observations (observed innovation input=0)		1302		5557
Uncensored Observations (observed innovation input>0)		4632		377

Marginal effects reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All regressions include sector dummies.

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

Table 5 shows results for the aggregate (column (i)) as well as for all four types of innovation output defined above (columns (ii)-(iv)). 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 as described in Table 2. The numbers in the table correspond to marginal effects from probit estimations.

We find that predicted innovation intensity increases the probability of obtaining any type of innovation output, including when the sample is restricted to firms with positive R&D investments. In terms of firm size, we find that larger and medium firms are more prone to obtain innovation output than smaller ones. Large-size firms are between 11 and 15 percent more likely to obtain any innovation output, while medium-size firms are around 8 percent more prone to obtain innovation outputs than smaller firms.

Concerning the sources of ideas for innovation as determinants of innovation output, we find that the probability of obtaining innovation outputs increases when innovation ideas come from internal sources and other firms' sources, such as the firm's headquarters, competitors, suppliers or clients. The fact that innovation ideas come from external sources increases the probability of obtaining any output in the R&D Model but only obtaining outputs related to adaptation of goods and services, process and managerial innovation in the case of the general Innovation Model.

We also find some puzzling results: firms with foreign capital are less likely to obtain innovation outputs, even though they invest more intensively with the interesting exception of innovation of goods and services in the R&D Model. Also, firms with greater capital stock appear to realize fewer true innovation results. Finally, 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 (see Table 3). Nevertheless, we find that firms with R&D departments are more likely to see results in goods and services adaption and process innovation.

Table 5. Knowledge Equation

VARIABLES	Model I - Innovation					Model II - R&D				
	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
	(i)	(ii)	(iii)	(iv)	(v)	(i)	(ii)	(iii)	(iv)	(v)
Innovation-related Variables										
Innovation Intensity (Predicted)	0.1393**	0.1056**	0.0903***	0.1716***	0.0717**	0.1008***	0.0866***	0.0710***	0.1318***	0.0630***
	(0.057)	(0.044)	(0.018)	(0.043)	(0.033)	(0.032)	(0.029)	(0.015)	(0.027)	(0.024)
Use of Public Policy Innovation Instruments	0.0958***	0.1118***	0.0643***	0.0660	0.0846*	0.1307***	0.1469***	0.1066***	0.1262***	0.1115***
	(0.026)	(0.030)	(0.023)	(0.043)	(0.044)	(0.029)	(0.035)	(0.022)	(0.044)	(0.041)
Human capital indicators										
High Qualified Workers	-0.2235	-0.0132	-0.0913*	-0.3628***	-0.0065	-0.3384**	-0.1397	-0.1879***	-0.5346***	-0.1093
	(0.142)	(0.081)	(0.047)	(0.084)	(0.105)	(0.154)	(0.100)	(0.057)	(0.116)	(0.135)
Qualified Workers	-0.0252	0.0288	-0.0061	-0.0559	0.0397	-0.0286	0.0151	-0.0148	-0.0689	0.0261
	(0.056)	(0.037)	(0.041)	(0.064)	(0.057)	(0.052)	(0.032)	(0.043)	(0.062)	(0.058)
R&D Department	-0.0063	0.0418**	0.0157	0.0482***	0.0086	-0.0285*	0.0201	-0.0022	0.0172	-0.0081
	(0.016)	(0.017)	(0.013)	(0.017)	(0.015)	(0.017)	(0.015)	(0.012)	(0.019)	(0.018)
Sources										
Intenal sources	0.3588***	0.3185***	0.0871***	0.2713***	0.2741***	0.4563***	0.3840***	0.1394***	0.3749***	0.3184***
	(0.037)	(0.025)	(0.014)	(0.025)	(0.022)	(0.019)	(0.023)	(0.012)	(0.019)	(0.019)
Other firms sources	0.0919***	0.0945***	0.0260*	0.1152***	0.0849***	0.1246***	0.1230***	0.0526***	0.1609***	0.1054***
	(0.014)	(0.017)	(0.013)	(0.023)	(0.016)	(0.013)	(0.010)	(0.013)	(0.021)	(0.016)
Specialized groups	0.0244	0.0212	0.0191	0.0002	0.0194	-0.0086	-0.0049	-0.0038	-0.0418*	0.0008
	(0.032)	(0.039)	(0.020)	(0.026)	(0.033)	(0.037)	(0.041)	(0.018)	(0.024)	(0.033)
External relationships	0.0308	0.0630***	0.0074	0.0556*	0.0917***	0.0767***	0.0970***	0.0389***	0.1135***	0.1145***
	(0.044)	(0.024)	(0.015)	(0.032)	(0.022)	(0.029)	(0.016)	(0.015)	(0.026)	(0.019)
Firm Characteristics										
International Competition	0.0162	-0.0040	0.1506***	-0.0471***	0.0041	0.0300**	0.0055	0.1604***	-0.0308**	0.0102
	(0.017)	(0.016)	(0.015)	(0.018)	(0.017)	(0.015)	(0.015)	(0.015)	(0.016)	(0.018)
Foreign Capital Ownership	-0.1681***	-0.1002***	-0.0141	-0.0956**	-0.0643	-0.0494	-0.0186	0.0605***	0.0339	-0.0075
	(0.053)	(0.038)	(0.014)	(0.039)	(0.040)	(0.036)	(0.034)	(0.017)	(0.038)	(0.035)
Capital stock	-0.0071	-0.0051	-0.0072**	-0.0098	-0.0020	-0.0014	-0.0017	-0.0038	-0.0034	0.0000
	(0.007)	(0.004)	(0.003)	(0.007)	(0.006)	(0.004)	(0.002)	(0.003)	(0.005)	(0.005)
Age										
Age	-0.0002	0.0000	-0.0001	0.0000	-0.0000	-0.0003**	0.0000	-0.0001	-0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age squared	0.0000	-0.0000	0.0000*	0.0000	-0.0000	0.0000	-0.0000	0.0000	-0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size										
Medium	0.0749***	0.0725***	0.0535***	0.0749***	0.0875***	0.0771***	0.0742***	0.0555***	0.0777***	0.0883***
	(0.013)	(0.020)	(0.014)	(0.020)	(0.018)	(0.012)	(0.020)	(0.014)	(0.020)	(0.017)
Large	0.1057***	0.1478***	0.1157***	0.1347***	0.1345***	0.1151***	0.1567***	0.1286***	0.1507***	0.1410***
	(0.019)	(0.027)	(0.020)	(0.028)	(0.023)	(0.019)	(0.027)	(0.019)	(0.030)	(0.024)
Observations	4632	4632	4632	4632	4632	377	377	377	377	377

Marginal effects reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

All regressions include sector dummies.

Finally we present results from estimating the performance equations, using both productivity (TFP) and sales per worker as dependent variables. These estimations 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 find a significant effect of innovation of goods and services and of processes on TFP of firms that invest in any innovation activity as well as in R&D. In addition, for the firms investing in R&D, innovation in managerial and marketing has a positive effect on TFP. We also find evidence that these effects are persistent over time.

However, when measuring performance as sales per worker we find that adaptation in goods and services positively have a positive and significant effect although it seems to disappear over time, especially in the case of firms investing in R&D. This is also the case for innovation in goods and services and managerial and marketing activities. On the other hand, innovation in production processes seems to have a lagged effect on sales per worker performance, especially in the case of R&D investing firms.

We find other results that are commonly found in the firm productivity literature (see Arbeláez, Echavarría and Rosales, 2006, for example): size, skilled labor and exporting activities are positively related to productivity. 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 greater access to funds to finance innovation activities.

Furthermore, the variable related to exports (international competition) has a significant effect on productivity. 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—help to explain the positive association that we found between exports and productivity.

Finally, when looking at the estimations of aggregate innovation output we find similar result to those described above, except for the fact that innovation does not seem to have a contemporaneous effect when performance is measured as sales per worker for the larger sample of firms.

Table 6. Performance Equations for Types of Innovation Outputs

VARIABLES	Model I - Innovation			Model II - R&D		
	TFP			TFP		
	2004	2005	2006	2004	2005	2006
	(i)	(ii)	(iii)	(i)	(ii)	(iii)
Innovation Types						
Adaptation	0.2090	0.1551	0.1847	0.7547	0.6974	0.7188
	(0.515)	(0.678)	(0.611)	(0.574)	(0.685)	(0.553)
Innovation	0.5150***	0.3714*	0.4934***	0.2618*	0.1389	0.2613**
	(0.116)	(0.207)	(0.110)	(0.141)	(0.199)	(0.132)
Innovation in Processes	0.7509*	0.8706*	0.9557**	2.4165***	2.3608***	2.4177***
	(0.450)	(0.420)	(0.447)	(0.547)	(0.381)	(0.549)
Innovation in Management and Marketing	0.5183	0.7747	0.7785	1.9287**	1.9810**	1.9593***
	(0.666)	(0.861)	(0.654)	(0.781)	(0.718)	(0.655)
Human capital indicator						
High qualified	0.8502***	0.8276***	0.6581***	0.6447***	0.6415**	0.4753***
	(0.131)	(0.214)	(0.151)	(0.127)	(0.226)	(0.153)
Qualified	-0.0567	-0.0370	-0.0475	0.0905	0.0661	0.0752
	(0.077)	(0.063)	(0.093)	(0.077)	(0.064)	(0.095)
Age						
Age	-0.0016***	-0.0015***	-0.0014***	-0.0017***	-0.0016***	-0.0015***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age squared	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size						
Medium	0.1198***	0.1125*	0.0850**	0.1198***	0.1125*	0.0850**
	(0.031)	(0.061)	(0.034)	(0.031)	(0.061)	(0.034)
Large	0.2495***	0.2148*	0.1998***	0.2495***	0.2148*	0.1998***
	(0.047)	(0.115)	(0.047)	(0.047)	(0.115)	(0.047)
Constant	8.1677***	8.0000***	6.9483***	8.1366***	7.9757***	6.7072***
	(0.626)	(0.152)	(0.545)	(0.742)	(0.141)	(0.623)
Observations	4632	4632	4632	377	377	377
R-squared	0.211	0.191	0.174	0.212	0.193	0.176

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All regressions include sector dummies.

Table 6. Performance Equations for Types of Innovation Outputs (Continued)

VARIABLES	Model I - Innovation			Model II - R&D		
	Sales per worker			Sales per worker		
	2004	2005	2006	2004	2005	2006
	(i)	(ii)	(iii)	(i)	(ii)	(iii)
Innovation Types						
Adaptation	2.6253***	3.5293**	1,817	2.5336***	0.6184	1,319
	(0.714)	(1.448)	(1.993)	(0.660)	(1.528)	(2.055)
Innovation	0.6183**	0.1914	1,207	0.7079***	1.7742**	1,394
	(0.295)	(0.564)	(0.975)	(0.261)	(0.755)	(0.855)
Innovation in Processes	1.1104*	3.1634***	6.5014***	0.5666	1.9176	5.7883***
	(0.615)	(1.043)	(1.925)	(0.653)	(1.248)	(1.930)
Innovation in management and marketing	2.1492***	0.9829	3,059	2.7109***	0.3942	2,712
	(0.829)	(1.489)	(2.232)	(0.820)	(1.858)	(1.868)
Human capital indicators						
High qualified	1.9672***		2.6134***	1.8999***	1.9420***	2.4583***
	(0.169)		(0.547)	(0.167)	(0.544)	(0.534)
Qualified	0.3783***		0.3308	0.3658***	0.5490**	0.3091
	(0.094)		(0.259)	(0.088)	(0.218)	(0.288)
Firm Characteristics						
International Competition	0.4848***	0.3259**	0.7881***	0.4894***	0.7108***	0.7870***
	(0.069)	(0.131)	(0.200)	(0.065)	(0.190)	(0.226)
Foreign capital indicator	0.4720***	0.6178***	0.0861	0.4672***	0.4746***	0.1390
	(0.070)	(0.118)	(0.230)	(0.065)	(0.136)	(0.183)
Age						
Age	-0.0004*	-0.0001	0.0017*	-0.0005**	0.0001	0.0016**
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Age squared	0.0000***	0.0000	-0.0000	0.0000***	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size						
Medium	0.1333***	0.3364***	0.4522**	0.1287***	0.4232***	0.4420***
	(0.041)	(0.080)	(0.158)	(0.033)	(0.115)	(0.109)
Large	0.3692***	0.4627***	0.8911***	0.3798***	0.7023***	0.8704***
	(0.076)	(0.143)	(0.288)	(0.073)	(0.233)	(0.179)
Constant	10.7795***	8.1903***	7.6544***	10.7587***	8.8907***	7.5265***
	(0.420)	(1.349)	(0.334)	(0.420)	(0.231)	(1.534)
Observations	4632	4632	4632	377	377	377
R-squared	0.250	0.100	0.086	0.251	0.107	0.086

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, '
All regressions include sector dummies.

Table 7. Performance Equations for Aggregate Innovation Output

VARIABLES	Model I - Innovation			Model II - R&D		
	TFP			TFP		
	2004	2005	2006	2004	2005	2006
	(i)	(ii)	(iii)	(i)	(ii)	(iii)
Aggregate Innovation Output	0.1299**	0.1282**	0.1206**	0.1118*	0.1132**	0.1037**
	(0.057)	(0.046)	(0.044)	(0.058)	(0.045)	(0.047)
Human capital indicator						
High qualified	1.0303***	0.9983***	0.8621***	1.0333***	1.0008***	0.8647***
	(0.183)	(0.218)	(0.151)	(0.182)	(0.217)	(0.150)
Qualified	-0.0140	0.0062	0.0019	0.0124	0.0073	0.0034
	(0.051)	(0.065)	(0.076)	(0.051)	(0.065)	(0.076)
Age						
Age	-0.0016***	-0.0014***	-0.0014***	-0.0016***	-0.0015***	-0.0014***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age squared	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size						
Medium	0.1764***	0.1601**	0.1448**	0.1764***	0.1601**	0.1448**
	(0.056)	(0.060)	(0.052)	(0.056)	(0.060)	(0.052)
Large	0.3730***	0.3078***	0.3211***	0.3730***	0.3078***	0.3211***
	(0.056)	(0.087)	(0.074)	(0.056)	(0.087)	(0.074)
Constant	7.5125***	7.2842***	7.1066***	7.5238***	7.2938***	7.1189***
	(0.102)	(0.117)	(0.085)	(0.103)	(0.119)	(0.086)
Observations	4632	4632	4632	377	377	377
R-squared	0.208	0.189	0.171	0.208	0.189	0.170

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

All regressions include sector dummies.

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

VARIABLES	Model I - Innovation			Model II - R&D		
	Sales per worker			Sales per worker		
	2004	2005	2006	2004	2005	2006
	(i)	(ii)	(iii)	(i)	(ii)	(iii)
Aggregate Innovation Output	0.1316	0.9205***	1.4295***	0.1254	0.9249***	1.4493***
	(0.109)	(0.113)	(0.182)	(0.110)	(0.112)	(0.185)
Human capital indicators						
High qualified	1.7268***	1.6890***	1.7996***	1.7264***	1.6797***	1.7825***
	(0.320)	(0.399)	(0.328)	(0.320)	(0.399)	(0.329)
Qualified	0.3465***	0.4921**	0.1945	0.3468***	0.4900**	0.1897
	(0.100)	(0.211)	(0.232)	(0.100)	(0.211)	(0.232)
Firm Characteristics						
International Competition	0.3481***	0.3352***	0.3956**	0.3482***	0.3317***	0.3890**
	(0.068)	(0.104)	(0.154)	(0.068)	(0.104)	(0.155)
Foreign capital indicator	0.4728***	0.4288***	0.0459	0.4780***	0.4664***	0.1045
	(0.081)	(0.136)	(0.225)	(0.079)	(0.137)	(0.224)
Age						
Age	-0.0005***	0.0004	0.0017*	-0.0005***	0.0004	0.0017**
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Age squared	0.0000***	-0.0000	-0.0000	0.0000***	-0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Size						
Medium	0.1639**	0.3913***	0.4054**	0.1645**	0.3884***	0.3990**
	(0.067)	(0.107)	(0.144)	(0.067)	(0.107)	(0.143)
Large	0.3331**	0.5742***	0.8598***	0.3334**	0.5660***	0.8444***
	(0.120)	(0.181)	(0.228)	(0.119)	(0.180)	(0.226)
Constant	9.8669***	9.9950***	9.1354***	9.8702***	9.9828***	9.1085***
	(0.110)	(0.145)	(0.170)	(0.112)	(0.147)	(0.175)
Observations	4632	4632	4632	377	377	377
R-squared	0.249	0.107	0.084	0.249	0.107	0.085

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, '

All regressions include sector dummies.

7 Conclusions

Innovation activities may promote growth rates since it has a direct and positive impact on productivity. In order to assess the relevance of innovation, this paper establishes a formal relationship between innovation and productivity for Colombian firms. In general terms, we show strong evidence that innovation improves productivity.

Specifically, we found that adaptation (innovation that results in goods and services new to the firm and to the domestic market) enhances firms' sales per worker but not Total Factor Productivity, but innovation (that result in introducing new goods and services to the international market) boosts both sales and TFP. In the same way, innovation in processes improves firms' productivity and sales. Finally, innovation in marketing and management positively impact sales per worker contemporaneously, and enhance TFP when investment is made in R&D.

We also studied the factors behind firms' decision to invest in innovation and the intensity of such investment. We found that large and medium firms innovate more intensely than small firms, as well as exporting firms, firms with foreign ownership and capital-intensive firms. However, investment in R&D is negatively affected by foreign ownership. Additionally, human capital appears to be highly relevant for total innovation and for R&D, as well as the existence of an R&D department inside the firm. We also found that public financing for innovation is highly relevant for investing in innovation and R&D, and public instruments are effective promoters of total innovation. Similarly, the existence of formal protection methods is an important determinant of the decision to innovate and is especially relevant for R&D investments. The origin of innovation ideas matters for investing in innovation (but is irrelevant for R&D), and a strong effect is observable when ideas come from external relationships (e.g., universities, consultants and information systems).

Finally, we estimated the returns to investment in innovation. The main results were that greater innovation efforts significantly increase the probability of obtaining any innovation output. Additionally, the use of public policy innovation instruments enhances the likelihood of obtaining innovation results. Firm size is important in innovating, and larger firms are more prone to achieve innovation outputs than smaller ones. On the other hand, exporting firms achieve better results in innovation in goods and services and in processes, while, surprisingly, firms with foreign capital ownership tend to achieve innovation outputs. We also found that innovation ideas coming from inside the firms and from other firms' sources facilitate the successful achievement of successful of all kinds of innovation, while ideas coming from their relationships with universities, research centers and other external agents help in obtaining goods and services adaptation, innovation in management and marketing and all outputs when investment took place in R&D.

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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 Leeuwen & 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. (2006)	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

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	
Duguet (2006)	-	-	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 (2004)	-	-	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

Key

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
OR	Organizational rigidities
LQP	Lack of qualified personnel.
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	Full 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

obstacles
strategy
Sources of information

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.

Sources of Innovation:

- *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.

- *Other 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 patents, trademarks, or copyright to protect inventions or innovations during 2004.

Formal Protection industry: The total patterns of industry minus firm's patents between 1996-2004.

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 two groups: medium and large.

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