WPS4443

Policy Research Working Paper 4443

Human Capital and University-Industry Linkages' Role in Fostering Firm Innovation:

An Empirical Study of Chile and Colombia

Daniela Marotta
Michael Mark
Andreas Blom
Kristian Thorn

The World Bank
Latin American and the Caribbean Region
Human Development Sector Unit
December 2007

Policy Research Working Paper 4443

Abstract

A firm's absorptive capacity, human capital and linkages with knowledge institutions have been shown to increase the firm's probability of innovating in OECD economies. Despite its importance for national- and firm-level competitiveness, few papers examine the impact of the same variables for firms innovation in Latin America. This paper investigates the link between firm innovation and its absorption capacity as proxied by the presence of a R&D department, the firm's human capital, and its interaction with research centers and universities. We analyze the case of Chilean and Colombian manufacturing firms using data from innovation surveys. A probit regression model is applied to identify the determinants of innovation activity. We find that collaboration with university and research institutions is associated with an increase in the probability of introducing a new product in Chilean and Colombian firms of 29 and 44 percent, respectively, and it can increase up to 58 percent in the case of Colombian firms interacting with research centers. Moreover, firms whose employees have a higher level of education, or whose managers/supervisors have a higher (perceived) level of knowledge, are more likely to innovate. Although the estimates could be affected by biases and suffer from shortcomings in data, the findings suggest that policies and incentives to increase firm-level human capital and industry-university linkages are important to increase innovation in Latin America.

This paper—a product of the Human Development Sector Unit, Latin American and Caribbean Region—is part of a larger effort in the region to support client country's improve economic competitiveness through investments and policy reforms of tertiary education and the innovation system. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at dmarotta@worldbank.org.

Human Capital and University-Industry Linkages' Role in Fostering Firm Innovation: An Empirical Study of Chile and Colombia

Daniela Marotta[1] Michael Mark Andreas Blom[2] Kristian Thorn

World Bank
1818 H Street
Washington D.C. 20433
U.S.A.

The authors would like to thank Colombia's *Departamento Administrativo Nacional de Estadística* (DANE) and the Chile's Executive Secretary of Technological Innovation Program and the National Institute of Statistics. The authors also thank Prof. Lucia Cusmano of Center for Research on Innovation and Internationalisation Processes at Bocconi University and several World Bank colleagues for comments.

[1] Email address: dmarotta@worldbank.org
[2] Email address: ablom@worldbank.org

1. INTRODUCTION

In recent years, there has been a growing interest in the contribution of knowledge to total factor productivity (TFP), generally associated with technological progress, and sustainable long-term economic development. The main reason for investigating the effects of human capital and knowledge transfer on innovation, productivity and economic growth is the widespread belief that resource-driven economic growth that does not rely on knowledge is subject to diminishing returns and is not sustainable in the long term. This belief is sustained by both exogenous (e.g., Solow 1956) and endogenous growth models (e.g., Romer 1990; Grossman and Helpman 1991; Aghion and Howitts 1992), which reinforce the importance in economic theory of innovation as a driver of long-term productivity.

In this paper we investigate the case of two Latin American countries, Chile and Colombia, and present an analysis of the role of human capital and knowledge transfer between research centers, universities (the major centers of knowledge production) and firms in fostering innovation in both countries.

Chile and Colombia come from different past achievements in terms of growth. Chile, thanks to a strong macroeconomic and financial policy framework together with deep structural and institutional reforms, has managed to exploit its natural resources to achieve a high level of growth (although, recently, such growth has slowed), and it has become, with an average annual per capital growth rate of 4.1 percent, the fastest growing economy in Latin America since 1991 and a benchmark for reform in the whole region. Colombia, conversely, only potentially met the expectations of rapid growth following a process of liberalization, privatization and structural reforms (*Apertura*) embarked on in the 1990s, and only in recent years has achieved a high economic growth.

Notwithstanding these different starting points, nowadays both countries face the challenge of achieving equitable and sustainable economic development. In order to initiate a process of long-term growth, they need to ensure that they are ready to exploit the unlimited potential coming from innovation and technological progress, and that their investment both in the quality of human capital and in improving the institutional framework is directed respectively towards increasing learning capacity and vitalizing the country’s innovation system.

The paper is structured as follows. The next section presents a summary of the literature on innovation theory, followed by a short presentation of the innovation shortfalls in Latin America in general and Chile and Colombia in particular. Section 3 introduces briefly the model and presents the variables used in the analysis while section 4 presents some descriptive statistics. The results are shown in section 5; after proposing possible future extensions to the analysis in section 6, section 7 concludes.

2. BACKGROUND

Since the landmark article by Solow in 1956, the idea that technological progress is the main factor affecting growth, more than classical inputs such as labor and capital, has become widely accepted. Solow also presented the argument that cross country differences in technology might be the main cause of difference in income per capita. Several empirical studies have subsequently tested through cross country analysis the importance of TFP in explaining growth gap and shown that differences in TFP effectively account for roughly half of such gap.[3]

More recently, endogenous models (Romer 1990 and Aghion and Howitt 1992) have shed light on the determinants of TFP growth, linking TFP growth rate to innovation. According to this view, individual firms produce technological knowledge which, initially, is private to the firm but subsequently spills over to the rest of the economy as it can be copied at almost no cost by any number of firms, becoming social knowledge. With this spillover effect, an aggregate production function which would otherwise have either constant or decreasing returns to scale may exhibit increasing returns to scale allowing sustained long-run growth. An implication of this view is that a firm, when not able to innovate on its own, can benefit from the research findings of firms working along similar lines. However, as suggested by Cohen and Levinthal (1989 and 1990), utilizing public domain knowledge fruitfully is not without a cost and this cost is minimal only for firms that have accumulated sufficient technological capability (or absorptive capacity) to absorb external knowledge. Learning, i.e. knowing where the frontier is and determining which adaptations are necessary, is therefore considered to be a "second face" of R&D.[4]

As shown by recent studies, a firm's absorptive capacity is determined, together with the traditional indicators such as R&D or patents, by its human capital, defined as the stock of knowledge inside the organization. [5] In order to introduce new products and processes, firms must have the capacity to innovate and conduct R&D. De Ferranti et al.(2003) showed that efforts to stimulate innovation are unlikely to yield a high return if the efforts are not complemented by a sufficient stock of human capital. This is only strengthened by other evidence suggesting that technologies not only increase the demand for human capital skills but also that new technologies are adopted more extensively in companies with a high share of skilled workers. In other words, advanced human capital not only improves the possibility of companies engaging in innovation and R&D activities, but the skills of the workers also increase the firms' ability to absorb new knowledge and technologies.

Besides formalized knowledge, tacit knowledge is an important component of innovation (Rosenberg 1982, Dosi 1998, and Senker 1995). Absorptive capacity may be developed through the accumulation of experience and this kind of firm-specific knowledge may be measured by the work experience of the employees. Mangematin and Nesta (1999) argue that highly educated employees encourage engagement with other individuals with similar competencies outside the firm, thus facilitating access to external networks of knowledge.

Finally, Cohen and Levinthal (1994) recognize the importance of the strength of external relationships in the development of absorptive capacity. Development of close relationships may contribute to a firm's absorption capacity because such relationships

[3] See Hall and Jones (1999), Dollar and Wolf (1997) and Klenow and Rodriguez-Clare (1997).
[4] Cohen and Levinthal 1990.
[5] Among others, Mark (2005).

can create and strengthen information channels and "thicken" the knowledge flow, hence increasing the efficiency of transfer of tacit knowledge. Figure 1 in the Appendix shows the main factors influencing innovation output and their interaction.

This paper has been developed in a conceptual framework where the interaction between firms, institutions and organizations plays a role in bringing new products, new processes and new forms of organization into economic use. [6] The analysis starts from the assumption that the innovative capacity of firms and private sector is central to the technological progress of a country. The rest of this work investigates whether: (i) the absorption capacity of firms, proxied by the level of expenditure made on R&D[7] by the firms, (ii) human capital, represented by the level of education of management and employees of the firms, and (iii) the interaction with research centers and universities that helps the dissemination of knowledge have a significant impact on firms' innovative capacity, and consequently on the whole country's innovation system. We analyze in particular the case of Chilean and Colombian firms.

3. INNOVATION SHORTFALLS IN CHILE AND COLOMBIA.

In Latin America and the Caribbean region (henceforth LAC) in general, and Chile and Colombia in particular, there is evidence of what has been defined an "innovation failure" or deficiency of innovation. Many indicators show weaknesses in the capacity of Latin American firms to innovate and commercialize research in recent years and there is no indication of an inversion of this trend. As shown in Lederman and Maloney (2003), the two countries present clear evidence of underperformance both in innovation inputs (i.e. any type of innovation-related investment), in R&D investment relative to GDP and in innovation outputs, defined as both commercial patents and scientific publications.

Graphs 1a and 1b benchmark performance by researchers residing in Chile and Colombia in terms of patents and scientific publications, comparing them with the average of those in countries with the same levels of GDP, the same size of labor force and the same value of merchandise exports to the USA since the 1960s.[8] The graphs show how Chile and Colombia perform with respect to the average of similar economies (the zero line). The embedded tables report the countries' average absolute levels of innovation outputs by decades. A negative number on the vertical axis is evidence of under performance. Chile and Colombia have historically underperformed in patents by about 50%; the picture for scientific publications is somewhat worse for Colombia while Chile performed quite well in the 1980s but this performance was not repeated in the last decade.

Similar benchmarking can be performed with indicators of innovation inputs such as investment in R&D with respect to GDP. In Graph 2, Chile and Colombia appear to be

[6] Formal definitions of "institutions" stress the "persistent and connected set of rules, formal and informal, that prescribe behavioural roles, constrain activities and shape expectations" (Storper 1998).

[7] The Frascati Manual, produced by the OECD (1993) defines R&D as: "Research and experimental development comprises of creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".

[8] For more information please refer to Lederman and Maloney (2003)

substantially below trend with respect to the OECD countries and, again, this trend does not seem to have changed significantly in the recent years.

These low rates of investment are not due to low returns. Lederman and Maloney (2003) estimate that the country-wide economic returns to R&D in countries of Chile and Colombia's levels are respectively 60 and 80 percent. Using the estimated return to physical capital, and the US long run return to stocks as high and low cases for the opportunity cost of investment, it is suggested that Chile should invest between 2 and 8 times more, and Colombia between 4 and 10 times more in R&D than they did in the 1990s. Since the average returns to R&D investments are higher in less developed than in high income countries, it is legitimate to wonder why they did not invest more in R&D.

The low level of innovation outcomes, on the output side, may arise from inefficiencies in the way in which existing innovation-related resources are utilized through the National Innovation System (NIS). One way of estimating the efficiency of a NIS is by examining how R&D investments translate into commercial patents and how the "elasticity" of patents with respect to R&D investments compares to the world average.[9] Graph 3 shows the elasticity or sensitivity of patents with respect to R&D in Chile and Colombia and several comparator countries. The negative value can be interpreted as an indication of the extent to which the two countries underperform in patenting efficiency relative to the OECD average.

Another indicator of the weakness in the capacity of private firms to innovate and commercialize research is given by the discrepancy between R&D expenditures in the private and public sectors. If we draw a comparison with the OECD countries, we see that in the OECD, private firms finance two-thirds of the R&D expenses while in Chile the private sector finances only one-third of the R&D expenses. In Colombia the picture is similar, with only 7 out of 100 firms investing in R&D and a total of investments that reaches only 0.1% of GDP. According to a global survey of business executives, public-private collaboration in Chile and Colombia is rated respectively 3.2 and 3.5 on a 7 point scale[10]. This is well below that in high-income countries, where the average rating is 4.1. The main obstacles to this collaboration seem to be lack of trust, different working cultures and different motives of collaboration.

For the case of LAC as a whole, econometric exercises described in Bosch et al. (2003) show that the region's inefficiency can be explained by the lack of collaboration between the private sector and research organizations such as universities. Colombia and Chile seem to be as inefficient as the average LAC country. In a recent paper Benavente et al. (2005) state that Chile's low innovation performance compared to OECD standards and even in relation to countries with comparable levels of income has to be related to the low private R&D spending, fragmented innovation policy and lack of skilled workers and researchers. These are obstacles to innovation activities in spite of the presence of many macroeconomic framework conditions that could boost them.

[9] Bosch et al. (2003) discuss in detail how these elasticities are estimated and how they vary across regions of the world.

[10] Global Competitiveness Report (2005).

4. MODEL AND DATA

The model used in this paper to identify the determinants of successful innovation activity is a probit model regression. This model analyzes the impact of: (i) firms' absorption capability; (ii) human capital; and (iii) interaction with centers of knowledge production, on the probability that each firm introduces a successful innovation activity (after controlling for firms' characteristics that vary according to the dataset used for the different countries). Innovation activity is defined here according to Rogers (1998), and measured by output and input innovation indicators. [11] These indicators refer, from the output side, to production of new products, introduction of new processes, patents applications or grants, and increase in sales from new or improved products or processes. From the input side the innovation indicator refers to the amount of investment in innovation and R&D activities.

Table 1 below reports the indicators as identified by Rogers (1998).

Table 1 Measures of innovation

Output measure	Input measure
Introduction of new or improved products	R&D expenditure
Introduction of new or improved processes	Acquisition of technology from others (e.g. patents, licenses)
Intellectual property statistics (patents, trade mark and design applications and grants)	Expenditure associated with new products/processes
Innovation indicators linked to firm performance	Intangible assets (goodwill and capitalized R&D)
Percentage of sales from new/improved products or processes	Marketing expenditure for new products
	Training expenditures related to new/changed products/processes
	Managerial and organizational change

Source: Rogers 1998

The model specifies the probability for each firm of having a positive outcome of the binary variable y, where y represents a firm undertaking innovation activity (and therefore defined as "innovative).

The probit model is generally defined as

$$\mathbf{Pr(y=1|x) = \Phi(xb)}$$

where **Φ** is the standard cumulative normal probability distribution and **xb** is called the probit score or index.

The probit method fits discrete binary data by a maximum likelihood method to estimate the parameters. The Maximum Likelihood Estimator is an estimator for unknown vectors of parameters. The likelihood function is defined by $L(\bar{\theta}; y) = f(y; \bar{\theta})$. Maximizing the

[11] Rogers (1998) "The Definition and Measurement of Innovation". We will use only some of these indicators in the analysis, according to data availability.

likelihood function with respect to $\bar{\theta}$ means identifying a specific value, which is denoted $\hat{\bar{\theta}}$. This estimate maximizes the probability that a sample value has actually been observed.

The log-likelihood function for probit is

$$\ln L = \sum w_j \ln \Phi(x_j b) + \sum w_j \ln\left(1 - \Phi\left(x_j b\right)\right)$$

The widespread use of maximum likelihood estimator is largely due to a range of desirable properties. The major properties of the maximum likelihood estimator (MLE) are large sample or asymptotic ones. They hold under fairly general conditions. The properties are: consistency (true parameter value generated from large sample data), asymptotic normality (unknown parameters are asymptotically distributed as the original parameter), asymptotic efficiency (minimum variance in the class of consistent, asymptotically estimators), the score has zero mean and variance of the original parameter.[12]

The explanatory variables x_j are divided into 3 main groups: absorptive capacity, human capital and collaboration with knowledge centers. Additional variables on firms' characteristics and on innovation obstacles are added where available.

The surveys used for the analysis are the third National Survey of Technology Innovation in Firms for Chile and the second Survey of Development and Technological Innovation for Colombia. The surveys are mainly composed of qualitative data (answer yes/no to questions) and some concerns regarding the quality of the data have arisen during the preparation of this work, in particular regarding the Chilean survey (please refer to Annex 5 for concerns on data quality). However, these surveys represent the best-available source of statistical information on innovation in these countries at a firm-level and they are still instrumental in drawing some interesting conclusions on the main factors affecting firms' capacity to innovate.

The third National Survey of Technological Innovation in Firms was conducted in 2001 by Chile's Executive Secretary of Technological Innovation Program and the National Institute of Statistics. It contains data for the years 2001 and predictions for 2002. The survey had 896 respondents representing a weighted total population of 4,932 establishments. The present work focuses on the manufacturing sector, with a total of 706 respondents and 687 valid observations weighting to a total of 4,570 observations.[13] The main concern regarding this survey is that there is no information regarding the response rate. In this way, weighting the data might risk strengthening the underlying bias

[12] For more information on the properties of MLE, cfr, among others, Johnston and DiNardo (1997).

[13] The nature of the data is mainly qualitative, since the firms are often asked questions with a yes/no answer and only a few variables are of a strictly quantitative nature (these include the data on innovation and R&D expenditure). To overcome the problem of the qualitative nature of the data, a metric scale has been introduced, with 0 denoting a negative answer (meaning either "no", "none", or "0") and where a scale of 1 to 4 denotes a positive answer, with 1 representing the least positive answer and 4 the most positive. The data were collected at the firm-level. This means that if a firm has more than one establishment the questionnaire was sent to the central management, in order to capture all the innovation activities within the firm. This methodology is in line with the procedures adopted by Eurostat for collecting the Community Innovation Surveys.

resulting from the fact that the most innovative firms are more likely to answer to the survey.

The second Survey of Development Activities and Technological Innovation for Colombian manufacturing firms was conducted by the *Departamento Administrativo Nacional de Estadística* (DANE) and contains data for the years 2003 and 2004. The total number of companies in the manufacturing sector in Colombia is estimated to be 6,670; the survey reports data on 6,172 of them.[14]

In the next two subsections we report the list of dependent and explanatory variables used in the analysis, organized according to the scheme/structure mentioned above. A more detailed list of the variables is reported in the Annexes, table A.2.1 for Chile and table A.2.2 for Colombia.

4.1 DEPENDENT VARIABLES

Innovation expenditures are divided in the surveys into different areas, such as:

- Expenses for new machinery
- Training in innovation and product testing
- Patents, licenses, introduction and commercialization of new products
- R&D

A firm is regarded as innovative from an input side (and therefore y=1) if the sum of **expenditure on innovation**, in one of the forms reported above, is larger than 0.

From an output perspective, a firm is regarded as innovative if it innovates in products or processes, if it increases the percentage of innovation sales or produces or applies for new patents.

In this work a firm is regarded as innovative in terms of **product** if it has introduced at least one of the following:[15]

- A new technology for production
- A product that is known to the market but new to the firm
- A product that is new both to the market and to the firm

Product innovations are aimed at increasing market share or to open a new market space for the firm. Process innovations, on the other side, are developed to improve the existing value chain of the firm. The improved process should lower the cost of production and therefore make the product more profitable, reducing the break-even point, either by competing on price or by increasing sales. Though not as radical in their effect as product innovation, process innovations also provide a substantial economic benefit to the firm.

A firm is considered here as innovative in terms of **process** if it has introduced at least one of the following:

- A new technology that the firm deems important to improve existing processes.

[14] There is no use of weights in the survey.
[15] In the last 3 years in the case of the Chilean survey.

- Process technologies that are relevant to the improvement of processes known to the market but new to the firm.
- Process technologies that are relevant to the improvement of the existing process and that are new both to the firm and to the market.

In terms of **innovation sales**, the Chilean survey (the Colombian survey does not provide this type of information) asks the firms to report their innovation sales as a percentage of total sales. These percentages are divided in different groups and ranked from 1 to 5, varying from 0 to 100 percent of the total sales.[16] An increase in the percentage of a firm's innovation sales classifies the firm as innovative. This measure relies on the ability of the firms to correctly and consistently report such percentages and they are, in principle, a better assessment of past, rather than current, innovative activities.

The last measure of outcome innovation is in terms of **patents**. This measure combines patents held by the firms for technologies developed by the firms themselves, developed outside the firms, or simply technologies prepared and presented. In this broad sense patents, or simply grants for a new technology presented, represent a "new" advance on existing knowledge and can be regarded as proxy for innovative output. In the Colombian survey, data on six different types of IPRs are also considered.[17] A firm is considered **IPR innovative** if any of the six statements (please refer to footnote 17) is higher than zero. Initially the measure was restricted to only encounter patents, but the figure was simply too low to provide any variance in the empirical models.

4.2 Explanatory variables

The explanatory variables of the model have been divided in four groups: (i) characteristics of the firms, (ii) human capital and knowledge embedded in the organization, (iii) absorptive capacity, and (iv) collaboration (knowledge diffusion or linkages with centers of knowledge production or sharing). A complete list of variables and a brief description is reported in Annex 2, while some descriptive statistics are provided in Annex 3 (tables A.3.1 and A.3.2). Below the rationale for using the selected groups of variables as determinants of innovation is presented:

(i) **Firm's characteristics:** according to Schumpeter (1942), they play an important role in determining firms' innovative activity, and therefore it is important to control for them. [18] While we are not trying to test Schumpeter's hypothesis that innovation activity is promoted by large firms and by imperfect competition, it is

[16] With this type of dependent variable (in a ranked order), it is not possible to use the ordinary probit model. It is however possible to use an ordered probit model, which makes it possible to fully explore the information available in the survey. It is possible to show that the ordered probit model is a special case of the multinomial probit model showed in Chapter 3. Please refer to Daisuke Nagakura (2004) for a complete proof.

[17] The six types of IPRs answers to the following questions:

1. Number of patents the firm applied for during 1996 – 2004.
2. Number of registers of utility models the firm applied for during 2003 - 2004.
3. Number of registers of industrial design the firm applied for during 2003 - 2004.
4. Number of distinguishing signs and marks the firm applied for during 2003 – 2004.
5. Number of authors rights the firm applied for during 2003 – 2004.
6. Number of software registers the firm applied for during 2003 – 2004

[18] And also Galbraith (1952) and Arrow (1962).

nevertheless necessary to take into account characteristics such as firms' size, global orientation or sector specific activities. The firms' characteristics in the model are defined as:

- Firm size: measured here as the natural logarithm of the number of employees.
- Export orientation: used as a proxy of how globally oriented the firm is. Being open to global competition leads to a higher probability of being innovative, by introducing new products or processes to survive the increased competition (this variable is not available in the Colombian survey).
- Sector dummies: to control for sector specific activities.
- Firm age (for Chile): defined as 2001 minus start up year (natural log)
- Capital location (for Colombia): this variable defines whether the firm is located in the federal district of Bogota.

(ii) **Human capital:** Human Capital normally refers to the "knowledge" embedded in the employees or workers of a firm. A comprehensive definition includes both "general" knowledge, in terms of formal education, and "firm-specific" knowledge acquired through work experience. Normally the education level of employees is the most commonly used proxy for human capital. This type of data is available in the Colombia survey. Unfortunately, in case of Chile, the survey does not ask any question about the educational level of the employees but it asks how important, in a scale from 0 to 4, the production knowledge of managers, supervisors and workers is in fostering innovation capacity in the firm. Therefore our variable will be defined as a dummy, with value 1 if the response to the question was 3 or 4 on the scale range, and 0 otherwise. There are two observations regarding this variable for the Chilean survey that are worth noting: the first is that the question asked in the survey refers to knowledge of the production methods and not knowledge in terms of educational level, therefore is more linked to a "firm-specific" type of knowledge, of the same type that could be proxied by the number of years of work in the firm or in firms working in a related field; the second observation is more relevant, and it refers to the nature of the variable. This variable is in fact a purely perceptional proxy for human capital, since we implicitly assume that the firms' high rating of production knowledge of managers, supervisors or workers represents the actual embedded knowledge of these groups. This is quite a strong logical jump and therefore the results coming from this variable should be interpreted with caution. This observation applies to most of the variables of the Chilean survey that have a qualitative and perceptional nature.

Other explanatory variables that affect the educational level of workers are those regarding training and re-education. Normally, data on the quantity and frequency of training could be a proxy of how updated is the level of technical knowledge inside the firm, but unfortunately this kind of data is not available in our survey. What is available in fact is the type of training (organizational, innovation and development, etc.) for Colombian firms and a qualitative type of data regarding how important training and re-education embedded in management, supervisors or workers is considered inside the firm. In the latter case we model the answers as dummy variables, with the variables being equal to 1 for a positive answer to the above questions. Because of the qualitative nature of these data, and because of the limitation of the perceptional variable (as reported above), the importance of avoiding putting too much emphasis on the results related to it still holds. It is nevertheless worth reporting the degree to which training is perceived to be relevant in assuring a certain level of knowledge, and therefore in helping firms to be competitive and innovative.

The answers to questions in the Chilean survey regarding possible obstacles to the firms' innovative activity have also been modeled as explanatory variables of innovation inputs. They have been modeled as dummies, with 1 if the firms consider that either lack of skilled personnel or lack of experienced personnel has been an obstacle for them. There is a caveat in this however: firms might not experience any obstacle to their innovation activity simply because they are not innovating and therefore sometimes this variable does not necessarily represent the lack of a negative condition but rather the absence of a positive action (which is innovation activity).

(iii) **Collaboration on innovation:** in this group of variables collaboration with different partners from both public and private sectors is considered. In the case of Chile, the variables are constructed as dummies with positive value if the firms attribute importance (on a scale from 1 to 4) to collaboration with each of the following: universities, consultants, suppliers and other firms in influencing their innovation activity. For Colombia the variables are defined as dummies with value 1 if the firm reports collaboration with each of the following partners: universities, public and private research centers, suppliers, and/or other firms.

(iv) **Absorption capacity:** in this group, variables related to the firms' capacity to transform knowledge into new products or processes are considered. These variables are: [19]

- The presence of an R&D department inside the firm.
- Innovation intensity (defined as the share of innovation expenses per employee).
- Investment in education related to innovation.
- Permanent innovation activities (if it is considered important to have permanent innovation activity within the firm).

These variables, with the exception of the innovation intensity variable, are dummy variables. Innovation intensity is defined as the amount of innovation expenses related to the size of the firm, in terms of number of employees.

5. DESCRIPTIVE STATISTICS

[19] For the last three variables data are available for Chile only.

5.1 CHILE

In Chile, from the sample of firms belonging to the manufacturing sector, 42 percent appear to be innovative, according to the definitions presented above. Of this 42 percent, 25 percent are innovative without investing in R&D, therefore there are factors other than pure investment in research that drive the firm's innovative capacity. In this work we will try to measure the impact of these other factors and analyze the potential for non-R&D sources of TFP growth such as quality of management, human capital and communication systems for knowledge dissemination.

Data disaggregation shows that most R&D investment is in the Food industry, with 35 percent of total R&D expenditure, as shown in graph A.3.1. Following far behind there is the fabricated metal sector, and chemicals and rubber. As shown in the graph, there are sectors that are not investing in R&D at all, such as radio and television, or very little, as in tobacco, coal and fuel or medical. As reported in the Country Innovation Brief for Chile (World Bank), Chile has an innovative comparative advantage mainly in mining and agricultural and food processing equipment. This is reported after computing an index of "revealed comparative advantages", based on sectoral patent data, whose value indicates, for a given sector, whether the country has a comparative advantage in innovation in that sector. Graph A.3.2 shows the index for the top innovative industrial sectors during 1983-2000 and for the period 1963-1980, which helps to assess whether the structure of innovation has changed in the country in the past decades. The evidence reported is only partly consistent with the firms' R&D investment data collected from the survey. It appears in fact that recently only part of the R&D expenditure in the Food industry is converted into patents. While there is not always a strong correlation between investment in innovation and patent production (as mentioned above), it could be argued that targeted public policies designated to stimulate R&D in other sectors, which appear to have a stronger innovation comparative advantage, could be a fruitful avenue for future policy implementation in these areas.

As is the case for industrial sectors, there is also a significant bias from a geographical perspective. Firms with the highest expenditure in R&D are mainly located in the Metropolitan area of Santiago, the capital (see graph A.3.3). This is particularly interesting, if we consider that over recent years the interrelationships between technology, innovation and industrial location behavior have come to be seen as essential features of regional development. A common trend of research and policy thinking is to draw lessons from observations of particularly successful innovative region as a means of re-modeling both industrial and regional policy. In Chile, a recently completed study commissioned by the Government to Boston Consulting Group, analyses the most successful clusters in the region in order to extract models for industrial policy and investment that can produce the same positive results in less advanced regions of the country by adapting the model to local characteristics.

As shown in Graph A.3.4, more than 40 percent of the total expenditure in R&D is done in Chile by medium sized firms (with 50 to 250 employees), while big firms (more than 250 employees) make up just over 20% of total R&D. This is not necessarily surprising, in spite of the common view that big firms are more efficient in terms of performing innovation following R&D investment (since they are less constrained in terms of resources). In reality, these data indicate that SMEs in Chile are already investing in innovation and that if their capabilities are upgraded and a more comprehensive approach to innovation is undertaken, the potential for increasing productivity may be significant.

In Chile, when firms that are innovative in terms of output have been asked about their collaboration activity, the majority of them resulted to be actively engaged with universities (see graph A.3.5).

5.2. COLOMBIA

As shown in Table A.3.2, in Annex 3, 79 percent of the Colombian firms[20] can be defined as innovative in the model. Only 7 percent of these firms have R&D investments, which is an unusually small percentage. A further 53 percent said they had introduced a new product, while 47 percent of firms had introduced a new process. These figures are a little lower than corresponding figures from Chile where 58 percent have introduced new products and 53 percent new processes. One caution comparing these figures should be noted, i.e. Colombian figures are not restricted by any timeframe whereas the Chilean firms respond to innovations within a time period of three years.

The firm characteristics show that the clear majority of Colombian firms are small or micro (see graph A.3.6). Two thirds of all Colombian firms have less than 50 employees. Further, 37 percent are geographically located in or around the capital Bogotá and 10 percent have their own R&D department.

When focusing on the collaboration activity it is clear that this is very low when it comes to Colombian firms. Only around one or two percent of the firms have collaboration activities concerning innovation. The number of firms that employ PhDs or persons with a masters degree is low. Three percent of the Colombian firms employ a PhD while 7 percent employ a person with a masters degree. Twenty-six percent of the firms have employees holding a specialist degree (see graph A.3.7).

6. RESULTS

6.1. CHILE

Innovation inputs.

As a first step to investigate innovation determinants, we analyze the innovation input, modeling the determinants of innovation expenses in general and of R&D in particular (table A.4.1). In our specification, we control for sector specificities. The results show that mainly export activity, which proxies for the level of openness of the firms, and knowledge and training of the management, which is an interpretation of the concept of human capital of the firm, affect innovation positively and in a significant way in both specifications. Firm size does not seem to be an important factor in determining innovation expenditures in general, and R&D in particular for Chilean firms. It does show, however, a positive sign. This result is peculiar to Chile; size seems to be relevant instead in case of Colombian firms, coherently with literature. A positive sign for the lack of skilled personnel is quite unexpected but it confirms the spurious characteristic of the

[20] Data from the second Survey of Development Activities and Technological Innovation of Colombian manufacturing firms (2003 and 2004).

variable, and can be interpreted in the sense that the innovating firms are the only ones acknowledging the lack of skills in the personnel.

The **innovation output** are modeled in table A.4.2 according to the different type of output: patents, innovation sales, innovative products and innovative processes.

The four different models show some interesting results. In neither of them firm size have a significant impact on the outcome of innovation activity (if we exclude innovation in processes). This highlights the fact that there are other factors influencing the success of the ongoing process of turning innovation expenses into innovation outcome and the results presented below aim to identify some of these factors. According to a hypothesis recently presented in theory, the modern geography of innovation shows that innovation is more likely to occur in small and medium-sized enterprises because of the intervention of additional factors able to influence innovation outcomes[21]. While the small enterprises, in fact, would have neither the scale nor the risk-bearing capacity to invest into innovation inputs, they would instead take advantage of the collaboration and interaction with other agents and from the knowledge flow coming from the proximity with them. These types of collaboration vary from the typical business links with other firms (in particular suppliers, as emerges from the analysis, cfr table A.4.2) to the wider concept of knowledge-sharing that comes from linkages to knowledge institutions such as universities.

Collaboration with knowledge institutions. It is indeed clear from the results that collaboration with universities has an important impact on the outcome of innovation. From our computation of the marginal effects of the coefficients (table A.4.5), it appears that collaboration with universities could increase the probability of patent activity in the firm by 37 percent or the probability of introducing a new product by 29 percent. Universities, however, do not contribute to improve production processes in the firm. The results confirm that the contribution of universities is more research-based and therefore their outcome is likely to be new patents or new products. In order to identify, assimilate and exploit knowledge from the collaboration activities firms need to have a critical mass of absorption capacity.

Absorption capacity. The R&D department is a proxy of the firm having continuous R&D investments and as such significant absorption capacity. The results (Table A.4.2.) show that having a R&D department has a positive impact when the innovation outcome measures are more research based, i.e. patents or product innovation. This explanation is consistent with the finding that collaboration with universities increases the probability of patent activity and product innovation. Permanent innovation activities also have a positive impact on all the innovation outputs except patents, which is understandable. Investing in innovation training and as such increasing the innovation capacity of the labor has a positive impact on the different measures of innovation output.

Human capital. The proxy for human capital, i.e. the measure of high knowledge of production within different levels of the organization, seems to have a positive impact on the innovation outcome when the knowledge is embedded in the mid-level managers. Knowledge about production embedded in the top management does not significantly

[21] Iammarino and McCann (2006).

impact the innovation outcome, and in fact it has a negative sign in all the models (but significant only for innovation sales) while, on the other hand, the level of knowledge embedded in the top management seems to influence positively and significantly the innovation and R&D investment. A possible explanation of this result could be that managers' education is not always closely linked with the most recent knowledge about technology and management practices. Bearing in mind the limitation of the proxies of human capital used in this analysis, because of the nature and limitations of the data, it can still be noted that the high rating of managers' education and training influence positively and significantly the probability of product innovation. This result could be interpreted as the effect of tacit knowledge, considered a component of innovation that is at least as important as formalized knowledge. The accumulation of experience and firm-specific knowledge, established through learning by doing, and by extension, through training on the job, contributes to the development of absorption capacity in the firm and can be considered part of the firm's human capital. Nevertheless, more specific data on firms' human capital is required to ascertain the link between firms, human capital and innovation in Chile.

6.2 COLOMBIA

Innovation inputs.

Our analysis shows that firm size and the share of employees with secondary and tertiary education have a positive impact on innovative inputs (investment and R&D) in Colombian firms (see table A.4.3).

Size is indeed a common factor when analyzing innovation determinants and is confirmed by numerous studies. It is also interesting to see that the share of employees with tertiary education has a larger impact than the share of employees with secondary school education, and in particular the latter do not have a significant impact in determining the investment in R&D. This leads to the suggestion that the more research based the investments are, the higher is the demand for skilled personnel.

The sector to which a firm belongs has in some cases a significant influence on whether a firm has R&D activities or general innovation investment. Finally it is interesting to see that a geographical location in or around Bogotá has a negative impact on innovative activity. This finding is in our opinion worth further analysis in the future (as discussed in chapter 7).

Innovation outcomes

The innovation outcomes have been modeled in table A.4.4 according to the different types of output, classified on the basis of data available from the survey: product, process and IPR innovation. The impact of explanatory variables is reported below.

Firm characteristics. Firm characteristics, such as size or the presence of a R&D department inside the firm, a proxy of the firm's **absorption capacity**, are found to have a significant impact on innovation outcomes. Larger firms in Colombia and firms that have their own R&D department have a higher probability of successful innovation activity, in any of the different types of outcomes. From the computation of marginal effects (table A.4.6), the presence of a R&D department is thought to increase the probability of IPR innovation outcome by 40 percent (27 percent is the increase in the probability of introducing new products and 18 percent of introducing a new process). Location near the capital Bogotá only seems to significantly influence product innovation.

Human capital is an important factor. Even though there is a low level of human capital in Colombian firms and this is expected to seriously impair the ability to utilize innovation investment, the share of employees with tertiary education positively affects the possibility of introducing a new product (which is also positively influenced by the share of employees with secondary education) or a new process (Table A.4.4). These results are coherent with the traditional view (Nelson and Phelps 1965) that highly educated employees are more likely to be able to recognize, value and exploit new technical opportunities in the economy. In addition, they also fit with the analysis made within the relatively recent paradigm of the "learning economy" (Lundvall and Johnston 1994), where the role of higher educated people is made all the more important by their ability to adjust better than others to the rapid changes in knowledge allowing them to place themselves always at the knowledge frontier and preserve their role of innovators.

Collaboration on innovation. The analysis confirms that collaboration with universities, research centers or suppliers improves the introduction of new products or IPR innovation. It could be argued that only larger firms have the capacity to collaborate with universities and research centers, and as such these explanatory variables are proxies to firm size. The model controls for this by including firm size in the explanatory variables. Collaboration with universities does not seem to be significant in influencing the introduction of a new process, and this confirms what we have already presented above in the case of Chilean firms. From the marginal effect analysis (please refer to table A.4.6) it appears that collaborating with universities could increase the probability of innovating in products and IPRs respectively by 44 and 51 percent, while collaborating with research centers (public or private) would increase such probabilities by 58 and 57 percent. With all due caution in interpreting the marginal effects values, it is clear that such collaboration and the public-private linkages between firms and knowledge centers seem the most influential factor in determining innovation outcomes.

Training and re-education. If Colombian firms train and further educate their employees they improve their probability of innovating. This is particularly the case if the training and education activities are related to innovation and development or organization. Organizational training or education seem to affect the introduction of a new product or process but it does not seem to affect significantly IPR innovation. Quite surprisingly, the training and upgrade of education for management does not seem to have any positive or significant effect on the innovation capacity of the firms.

7. FURTHER ANALYSIS

The analysis in this paper suffers some limitations, most of which come from the surveys, which present inconsistency in the data. The work done for this analysis has dealt with some of these inconsistencies or found a plausible explanation for them. However, in some cases it is very difficult to eliminate them, partly because they are implicit in the structure of the analysis (as in the case of the Chilean survey and the perceptional nature of many variables, above all the variable used as proxy of human capital), partly because it would mean contradicting the results of the surveys (e.g. a considerable bias has been created by respondents that most likely have inserted 0 as value in their answers instead of putting a missing value, or not available). A possible aim for further research could be changing the nature of the questionnaire from the perception form to an objective nature.

Alternatively, it would be advisable to link the survey to other sources of information on the firms that are of quantitative nature. However, from current knowledge, it seems that the firms of the survey do not have an identifier, i.e. a unique code that could link the firm of the survey with other databases in which it could be possible to find, for example, accounting data. If this were possible, it would allow us to control for very important variables, for example the capital/labor ratio of each firm, the level of foreign ownership (if any), or whether they received any fiscal incentive that could help them to invest in R&D or training.

Finally, spatial analysis and the analysis of clusters (linkages between firms, their sectors and their geographical location), could also help us to understand if there are "trends" in innovation and if these trends are lead by centers of excellence or by main innovators, or both. This view is particularly important in developing countries, since it would allow us to explore the sustainability of a process of continuous innovations in clusters based on traditional industries.

All industrial clusters can in fact be characterized in terms of transaction costs and relation characteristics (classical industrial clusters theory) and also in terms of technological regimes and knowledge characteristics (evolutionary approach). It would be interesting to empirically analyze whether the nature of agglomeration effects is sensitive not only to the industrial structure but also to the stage of product life cycle and to changes in the underlying technological base. Technological and knowledge features alone are not a sufficient guide to the types of clusters that are likely to emerge, nor are industry characteristics. Knowledge and innovation processes, organizational, firm and industry-specific characteristics, and institutional and governance setting all play a role in explaining the diversity of industrial clusters and their evolutionary trajectories. Understanding this diversity, and in particular both the transaction costs features and the knowledge features of any particular cluster, is the base for any policy action aimed at improving regional industrial characteristics and development. Building regional innovation systems requires the formulation of regional economic development strategies, and it requires engaging universities and the productive sector in the formulation and implementation of these.

Further analysis should focus on the geographical aspects, and the possible consequences of knowledge spillovers on the innovation process of firms within clusters. The framework could be the same as the one underlying this paper, where the definition of innovation extends beyond formal R&D activities to include continuous improvement in product design and quality, the ability not only to generate but also to absorb and adapt new knowledge. In such analysis, the role of human capital would appear in a wider context, and, after controlling for as many explanatory variables as possible, given the available data, the results will be more indicative of the importance of firms' absorptive capacity and knowledge clusters.

8. CONCLUSION

Economic theory postulates that knowledge leads, through innovation and technological progress, to an increase in total factor productivity and hence economic growth. In addition, unlike traditional factors of production, knowledge is not subject to diminishing returns. If true, the increased creation, use, adoption and flow of knowledge in various forms will significantly improve the prospects of sustainable long-term economic development for many countries.

In this paper, the focus is on empirically assessing the effects of knowledge, including human capital and partnership with knowledge-production centers (such as universities or research centers) on the innovative capacity of firms, in particular for manufacturing firms in Chile and Colombia. A probit regression model has been applied to identify the determinants of successful innovation activity as well as the impact of each determinant. The main areas of the analysis are firm characteristics, human capital and the absorption capacity of the firm. Human Capital is generally defined as "knowledge" embedded in the employees or workers of a firm, normally proxied by workers' educational attainments. A comprehensive definition, however, includes both the "general" knowledge of the employees in terms of formal education and the "firm-specific" knowledge acquired with the work experience. A further elaboration of the definition of human capital (which leads to the concept of absorption capacity) includes also the firms' organizational framework and the development of a closer relationship with external actors, which can be extremely important in the determination of the firm's absorption capacity.

The main conclusion of the paper is that human capital and collaboration with universities, research centers and suppliers are important factors in determining a firm's capacity to innovate in Chile and Colombia. Moreover, firms whose employees have a higher level of education, or whose managers/supervisors have a higher (perceived) level of knowledge, are more likely to innovate. Education and external links can be seen as signs of higher absorptive capacity and this will in turn improve firms' innovative performance.

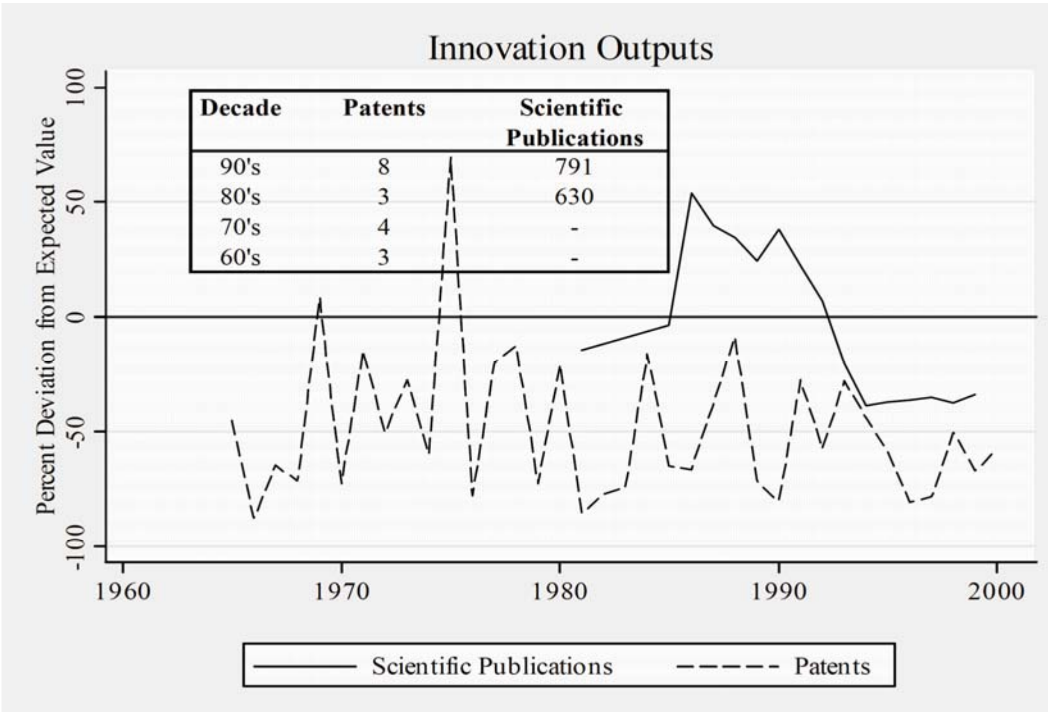
In spite of all the limitations of the analysis, it is possible to affirm from these results that improving collaborative research and other forms of university (or knowledge institutions) interaction with industry is one of the main requisites necessary to promote innovation efficiently. In addition, it is possible to argue that a well-educated and highly skilled population (and therefore labor force) is extremely important to the efficient creation, acquisition, dissemination and utilization of relevant knowledge, which creates innovation.

In a wider perspective, innovations are the result of all these interacting actors (firms, workers, knowledge institutions), and that these actors operate within a common institutional framework, defined as the “national system of innovation,” in which knowledge is created, distributed and utilized. The innovation performance is influenced by this institutional framework, by knowledge infrastructure, public-private linkages and, ultimately, government policy.

The policy suggestions emerging from this study substantiate the importance of reforms of national systems of innovation, especially in countries like Chile and Colombia, which seem to be lagging behind comparable countries in terms of innovation. Coherently with the results presented, human capital and absorption capacity are among the most important determinants of innovation ability. The most obvious policy consequence would be to assure that advanced human capital is produced through an improved higher education system. In addition to this, it would be critical to enhance public-private linkages, since interaction and the transfer of knowledge raise private sector innovation and further contribute to creating synergies and increasing the relevance of research carried out in public institutions, which would be otherwise disconnected from the productive world. To enhance linkages, some of the suggested instruments include support for public-private research partnerships and the financing of thesis work in industry, which would help to create a culture of innovation in private enterprises and provide for a substantial transfer of knowledge through the mobility of highly skilled labor.

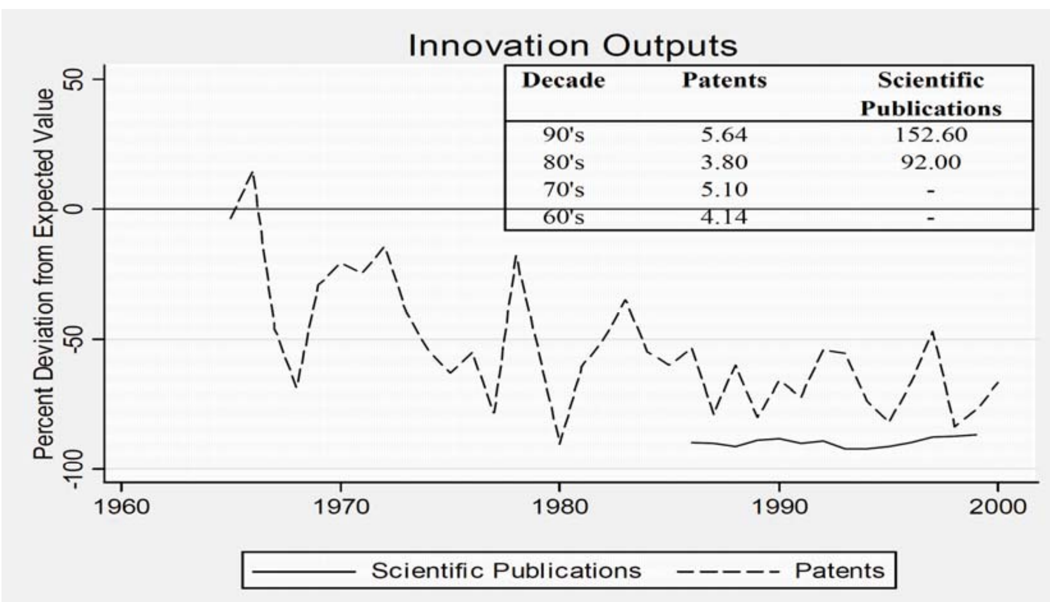
ANNEX 1:GRAPHS

Graph 1.a Chile: Innovation Outputs



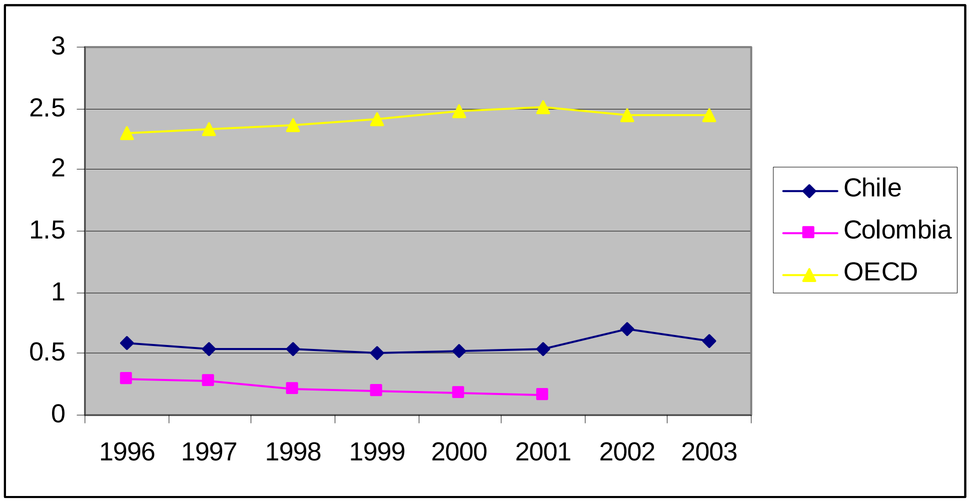
Source: Lederman and Maloney "R&D and Development" (2003)

Graph 1.b Colombia: Innovation Outputs



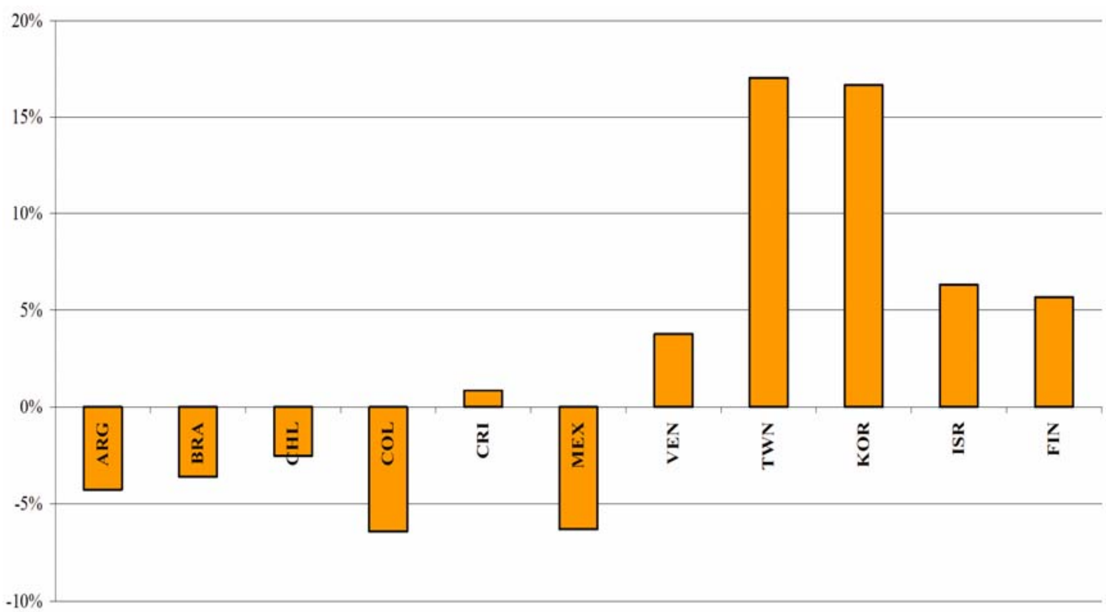
Source: Lederman and Maloney "R&D and Development" (2003)

Graph 2 Evolution of R&D Investment as % of GDP



Source: World Bank

Graph 3 Elasticity of Patents to R&D



Source: Bosch, Lederman and Maloney (2005)

ANNEX 2: VARIABLE DEFINITIONS.
Table A.2.1 Variable Definitions: Chile

Dependent variables:	**Definition**
Innovative	
R&D active	Dummy, 1 if R&D expenses reported >0
Patents	Dummy, 1 if the firm reports technologies developed by the firm, technologies developed outside of the firm or technologies prepared and presented.
Introducing new products	Dummy, 1 if the firm reports introduced new products in the years 1998 to 2000.
Introducing new process	Dummy, 1 if the firm reports introduced new processes in the years 1998 to 2000.
Percent of sales from innovation	
Explanatory variables:	
Increase in Sales	Dummy, 1 if the firm reports a rise in the sales from 1999 to 2000.
Old firms (Those elder than the average of sample)	Dummy, 1 if the firms are considered older than the average.
Firm size (ln size)	The natural logarithm to number of employees.
Firm age (ln age)	The natural logarithm to firm age.
Export	Dummy, 1 if the firm has reported exports activities.
Human capital	
Knowledge of managers rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Knowledge of supervisors rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Knowledge of workers rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Managers education and training rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Supervisors education and training rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Worker education and training rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Areas of education and training within the last 3 years	
Production and process rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Computers rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Management rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Languages rated high	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Innovation obstacles	
Lack of skilled personnel	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Lack of experienced personnel	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Industrial sector	Dummy, 1 if the firm fit into the category of a defined sector. The sector is determined by the CIIU2 and CIIU3 codes
Collaboration on innovation with	
Universities	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Consultants	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Suppliers	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Other firms	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Absorptive capacity	
R&D department	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Innovation intensity	$\frac{\text{innovation expenses}_i}{\text{number of employees}_i}$
Investment in innovation education	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4
Permanent innovation activities	Dummy, 1 if the responses stated 3 or higher on a scale from No to 4

Table A.2.2 Variable Definitions: Colombia

Dependent variables:	**Definition**
Innovative	Reported Innovation expenses>0
R&D active	Dummy, 1 if R&D expenses reported >0
Patents	Dummy, 1 if the firm reports technologies developed by the firm, technologies developed outside of the firm or technologies prepared and presented.
Introducing new products	Dummy, 1 if the firm reports introduced new products
Introducing new process	Dummy, 1 if the firm reports introduced new
Explanatory variables*:*	
Firm size (ln size)	The natural logarithm to number of employees.
Location	Dummy 1 if the firm is located in or around Bogotá.
Absorption capacity	
R&D department	Dummy, 1 if the firm responds positively to having a R&D department
Human capital	
Share of employees with high education	Share of employees in the firm with minimum a bachelor degree.
Share of employees with tertiary education	Share of employees in the firm with a tertiary education.
Share of employees with secondary school education	Share of employees with either apprentice or secondary school education in the firm.
Collaboration on innovation	
Universities	Dummy, 1 if the firm has responded positively to collaborating with universities.
Research center	Dummy, 1 if the firm has responded positively to collaborating with research centers.
Suppliers	Dummy, 1 if the firm has responded positively to collaborating with suppliers.
Internal	Dummy, 1 if the firm has responded positively to collaborating with other organizations within the group.
Other firms	Dummy, 1 if the firm has responded positively to collaborating with other private firms.
Training and re-education	
Innovation and development	Dummy, 1 if the firm has responded positively to the following types of training and re-education: innovation, improvement of production processes or development, improvement and design of products.
Organizational	Dummy, 1 if the firm has responded positively to the following types of training and re-education: management abilities or administration.
Management technology	Dummy, 1 if the firm has responded positively to the following types of training and re-education: information technology, industrial security, quality environment or others.
Sector	Dummy, 1 if the firm is placed in the sector defined by CIIU3 measures.

ANNEX 3: DESCRIPTIVE STATISTICS

Table A.3.1 Chile: Descriptive Statistics of the Included Variables

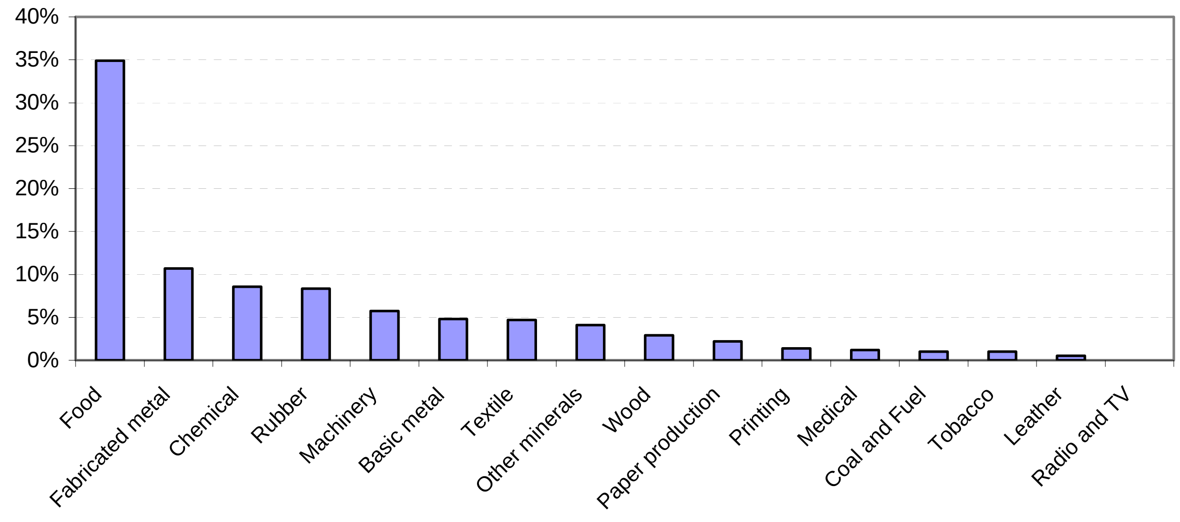
Variable	Mean	Max	Min	Obs (no weight)	Obs. (weight)
Innovative	0.42	1.00	0	706	4742
R&D active	0.17	1.00	0	706	4742
Patent activity	0.10	1.00	0	706	4742
Introduce new products	0.58	1.00	0	706	4742
Introduce new processes	0.55	1.00	0	706	4742
Located in capital area	0.58	1.00	0	706	4742
Export active	0.28	1.00	0	706	4742
Firm age (ln age)	2.88	5.55	0	704	4728
Firm size (ln size)	3.52	8.54	0	689	4584
Universities	0.04	1.00	0	706	4742
Consultants	0.06	1.00	0	706	4742
Suppliers	0.15	1.00	0	706	4742
Other firms	0.03	1.00	0	706	4742
R&D department	0.12	1.00	0	706	4742
Innovation intensity	0.71	82.05	0	689	4584
Investment in innovation education	0.17	1.00	0	706	4742
Permanent innovation activities	0.18	1.00	0	706	4742
Knowledge of managers rated high	0.76	1.00	0	706	4742
Knowledge of supervisors rated high	0.48	1.00	0	706	4742
Knowledge of workers rated high	0.25	1.00	0	706	4742
Managers education and training rated high	0.40	1.00	0	706	4742
Supervisors education and training rated high	0.42	1.00	0	706	4742
Worker education and training rated high	0.45	1.00	0	706	4742
Food, Beverages and Tobacco	0.25	1.00	0	706	4742
Textile, Wearing Apparel and Leather	0.18	1.00	0	706	4742
Wood and wood products, furniture	0.10	1.00	0	706	4742
Paper, printing and publishing	0.07	1.00	0	706	4742
Chemicals, petroleum, coal, rubber and plastics	0.13	1.00	0	706	4742
Non metallic mineral products, except products of petroleum and coal	0.04	1.00	0	706	4742
Basic metal industry	0.02	1.00	0	706	4742
Fabricated metal products, machinery and equipment	0.18	1.00	0	706	4742
Other manufacturing industries	0.02	1.00	0	706	4742

Source: Data from the 3rd National Survey of Technological Innovation in Firms in Chile.

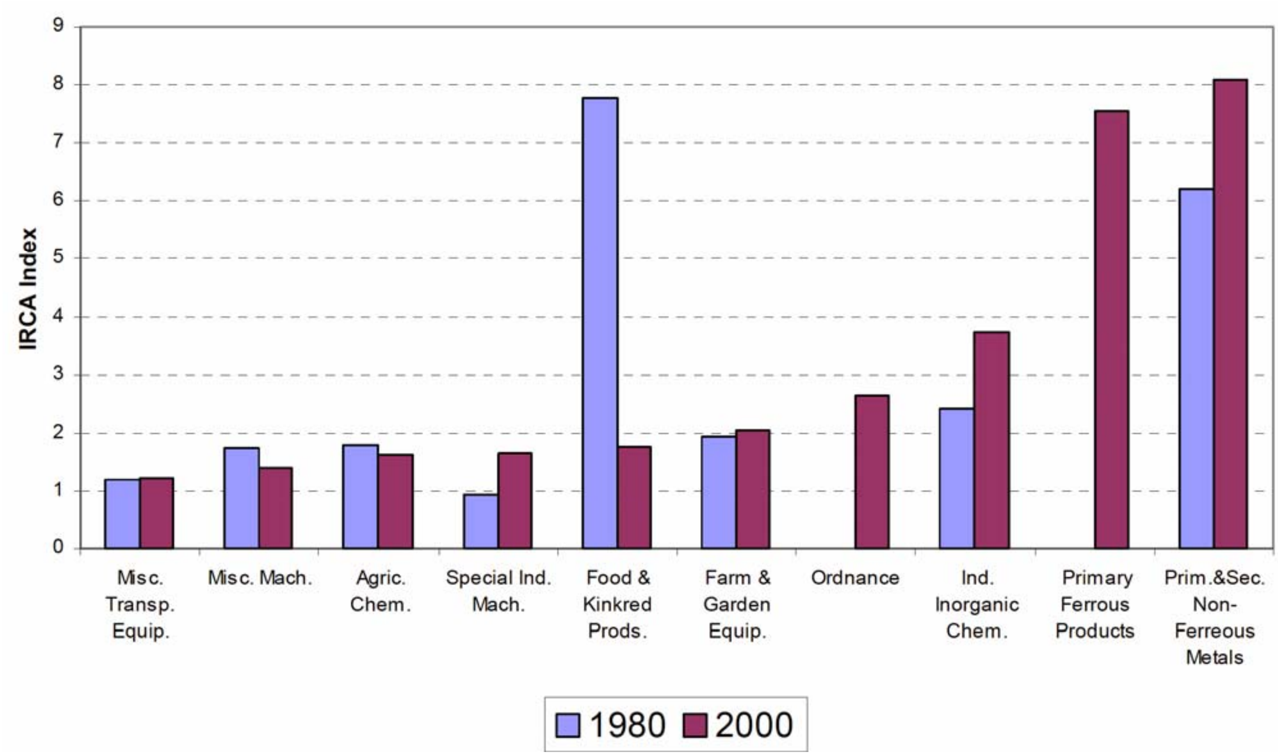
Table A.3.2 Colombia: Descriptive Statistics of the Included Variables

	Mean	Max	Min	Obs (no weight)
Dependent variable				
Innovative	0.79	1.00	0	6221
R&D active	0.07	1.00	0	6221
Patent active	0.01	1.00	0	6221
IPR active	0.05	1.00	0	6221
Introduce new products	0.53	1.00	0	6221
Introduce new processes	0.47	1.00	0	6221
Explanatory variables				
Firm characteristics				
Located in capital area	0.37	1.00	0	6221
Innovation intensity	2.89	13.0	0	6212
Micro firms	0.45	1.00	0	6221
Small firms	0.21	1.00	0	6221
Medium firms	0.27	1.00	0	6221
Big firms	0.08	1.00	0	6221
Absorption capacity				
R&D department	0.10	1.00	0	6221
Collaboration				
Universities	0.01	1.00	0	6221
Consultants	0.02	1.00	0	6221
Suppliers	0.02	1.00	0	6221
Internal	0.00	1.00	0	6221
Other firms	0.01	1.00	0	6221
Human Capital				
PhD	0.03	1.00	0	6221
Master	0.07	1.00	0	6221
Specialist	0.26	1.00	0	6221
Professional	0.85	1.00	0	6221
Assistant professionals	0.09	1.00	0	6221
Technologist	0.56	1.00	0	6221
Technician	0.58	1.00	0	6221
Apprentice	0.27	1.00	0	6221
Secondary school	0.93	1.00	0	6221
Primary school	0.60	1.00	0	6221
Training and re-education	0.53	1.00	0	6221
Sector				
Food	0.20	1.00	0	6221
Tobacco	0.00	1.00	0	6221
Textile	0.05	1.00	0	6221
Fur	0.11	1.00	0	6221
Leather	0.05	1.00	0	6221
Wood	0.02	1.00	0	6221
Paper production	0.03	1.00	0	6221
Printing	0.07	1.00	0	6221
Fuel	0.00	1.00	0	6221
Chemicals	0.08	1.00	0	6221
Rubber	0.08	1.00	0	6221
Other minerals	0.05	1.00	0	6221
Basic metal	0.02	1.00	0	6221
Fabricated metal	0.06	1.00	0	6221
Machinery	0.06	1.00	0	6221
Office machinery	0.00	0.00	0	6221
Electronic machinery	0.02	1.00	0	6221
Radio TV	0.00	1.00	0	6221
Medical	0.01	1.00	0	6221
Motor	0.02	1.00	0	6221
Other transport	0.01	1.00	0	6221
Furniture	0.07	1.00	0	6221
Recycling	0.00	0.00	0	6221

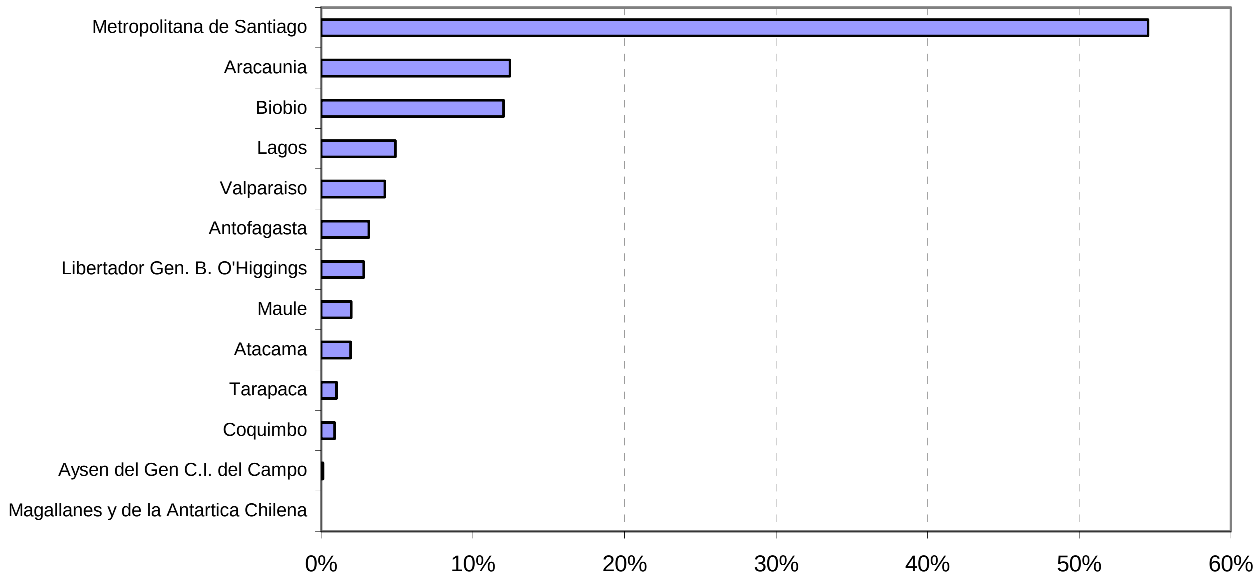
Graph A.3.1 Chilean Firms: R&D Expenditure by Sector



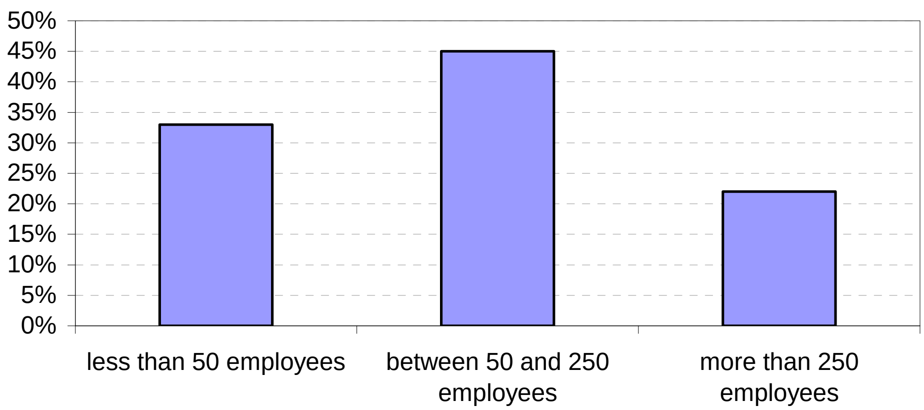
Graph A.3.2 Chile: Index of Innovation Comparative Advantage



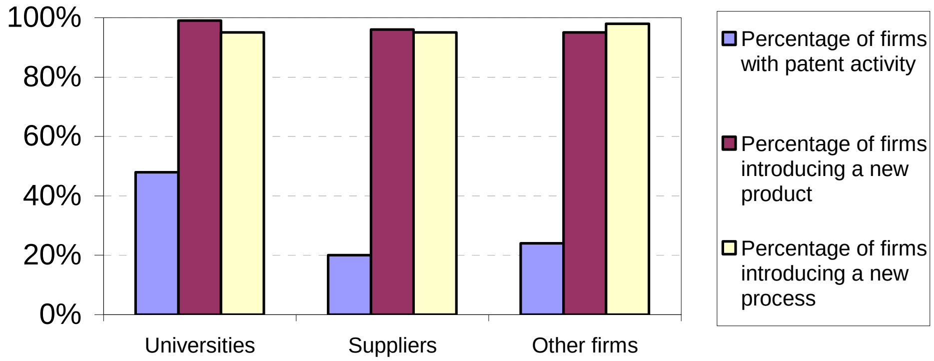
Graph A.3.3 Chile: Geography of R&D Expenditure



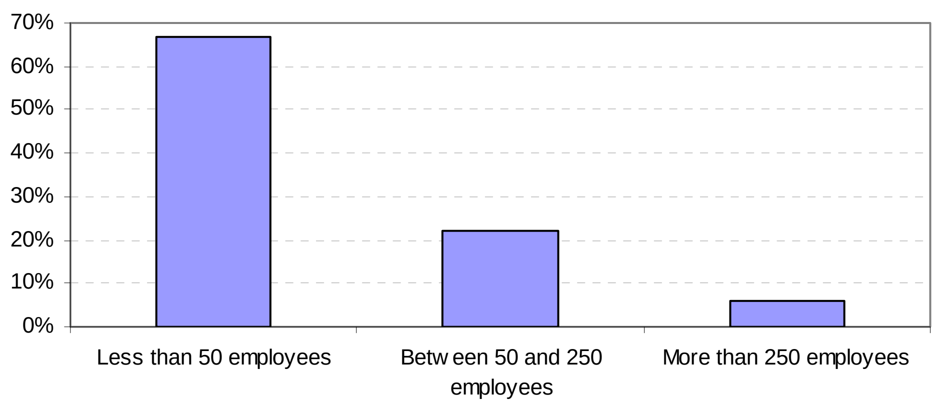
Graph A.3.4 Chile: Share of Total R&D Expenditure by Firm Size



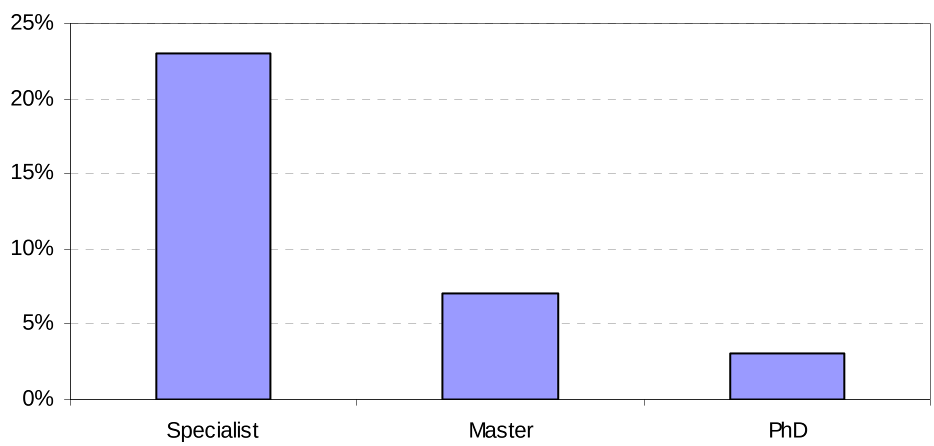
Graph A.3.5 Chile: Firms' Collaboration Activity



Graph A.3.6 Colombia: Firms' Size



Graph A.3.7 Colombia: Education Level of Firms' Employees



ANNEX 4: RESULTS
Table A.4.1 Results Chile: Innovation Input

	Innovation	**R&D**
Constant	-1.40	-1.68
Firm Characteristics		
Sales gone up	0.16	0.07
Old firms (Those elder than the average of sample)	-0.09	0.17
Firm size (ln size)	0.07	0.03
Firm age (ln age)	-0.09	**-0.32**
Export	**0.49**	**0.79**
Human capital		
Knowledge of managers rated high	**0.39**	0.17
Knowledge of supervisors rated high	0.16	-0.14
Knowledge of workers rated high	-0.01	0.07
Managers education and training rated high	**0.62**	**0.44**
Supervisors education and training rated high	-0.10	0.26
Worker education and training rated high	-0.02	0.23
Areas of education and training within the last 3 years		
Production and process rated high	0.33	0.15
Computers rated high	0.11	***0.32***
Management rated high	**0.46**	0.01
Languages rated high	0.07	**0.41**
Innovation obstacles		
Lack of skilled personnel	***0.28***	-0.14
Lack of experienced personnel	-0.03	0.31
Industrial sector		
Food, Beverages and Tobacco	Ref.	Ref.
Textile, Wearing Apparel and Leather	***-0.34***	-0.17
Wood and wood products, furniture	0.32	-0.33
Paper, printing and publishing	-0.10	-0.52
Chemicals, petroleum, coal, rubber and plastics	-0.02	0.14
Non metallic mineral products, except products of petroleum and coal	-0.40	0.00
Basic metal industry	-0.19	0.22
Fabricated metal products, machinery and equipment	-0.12	**0.52**
Other manufacturing industries	0.03	0.10
Observations	4570	4570
R^2	0.29	0.34
Log Likelihood	-332	-207

Note: **Bold** is denoting significance in a 5% level. **Bold** + *Italic* denotes significance in a 10% level.

Table A.4.2 Chile: Innovation Output

	Patents	Innovation sales	Product innovation	Process innovation
Constant	-3.21	N/A	-0.33	-1.28
Firm Characteristics				
Export active	***0.40***	0.11	0.04	**0.46**
Firm age (ln age)	**0.49**	0.04	***0.13***	0.01
Firm size (ln size)	-0.04	-0.06	-0.09	***0.13***
Collaboration on innovation with				
Universities	**1.48**	**0.53**	**1.49**	0.62
Consultants	-0.26	-0.10	0.39	0.50
Suppliers	**0.64**	0.28	**1.22**	**1.34**
Other firms	0.10	-0.09	-0.04	0.26
Absorptive capacity				
R&D department	**0.53**	0.16	**0.65**	0.35
Innovation intensity	0.02	0.02	**0.08**	**0.19**
Investment in innovation education	**0.62**	**0.54**	**0.98**	**0.72**
Permanent innovation activities	-0.12	**0.66**	**1.03**	**1.15**
Human capital				
Knowledge of managers rated high	-0.35	***-0.22***	-0.14	-0.02
Knowledge of supervisors rated high	***0.41***	**0.30**	**0.39**	**0.44**
Knowledge of workers rated high	**0.52**	**-0.49**	**-0.50**	**-0.58**
Managers education and training rated high	-0.36	**-0.24**	**0.59**	-0.11
Supervisors education and training rated high	0.10	**0.31**	-0.24	0.23
Worker education and training rated high	-0.41	0.10	0.28	0.22
Sector – Manufacturing				
Food, Beverages and Tobacco	Ref	Ref	Ref	Ref
Textile, Wearing Apparel and Leather	-0.01	***0.25***	0.12	0.00
Wood and wood products, furniture	**0.64**	**0.38**	***-0.37***	0.18
Paper, printing and publishing	0.30	**0.40**	-0.14	0.05
Chemicals, petroleum, coal, rubber and plastics	0.14	0.09	0.00	0.05
Non metallic mineral products, except products of petroleum and coal	-0.61	**0.68**	**1.16**	0.07
Basic metal industry	0.38	-0.25	***-0.77***	-0.11
Fabricated metal products, machinery and equipment	-0.20	0.03	0.03	0.12
Other manufacturing industries	-0.16	***0.25***	-0.32	-0.64
Observations	4570	4570	4570	4570
R^2	0.25	0.08	0.33	0.37
Log Likelihood	-164	-855	-311	-295

Note: **Bold** is denoting significance in a 5% level. ***Bold + Italic*** denotes significance in a 10% level.

Table A.4.3 Colombia: Innovation Inputs

	Innovation	R&D
Constant	-0.75	-2.18
Firms characteristics		
Firm size (ln #employees)	**0.47**	**0.20**
Capital location	**-0.15**	-0.04
Human capital		
Share of employee with tertiary	**0.30**	**0.36**
Share of employee with secondary	**0.15**	-0.09
Sector		
Food	Ref	Ref
Tobacco	N/A	**1.34**
Textile	**-0.32**	**-0.50**
Fur	**-0.30**	**-0.72**
Leather	0.11	-0.10
Wood	**-0.45**	-0.01
Paper production	0.08	-0.14
Printing	-0.09	**-0.57**
Fuel	0.22	***0.53***
Chemicals	0.04	**0.38**
Rubber	**-0.16**	**-0.25**
Other minerals	-0.14	0.12
Basic metal	-0.05	***-0.41***
Fabricated metal	-0.10	**-0.43**
Machinery	0.05	-0.02
Office machinery	N/A	N/A
Electronic machinery	0.07	-0.15
Radio TV	-0.10	0.33
Medical	0.14	0.28
Motor	0.04	0.08
Other transport	-0.30	-0.11
Furniture	-0.12	**-0.37**
Recycling	N/A	N/A
Observations	6208	6212
Log likelihood (χ^2)	-2756.78	-1394.62
R^2 (Pseudo)	0.13	0.10
Test		
Hosmer-Lemeshow chi2(8)	26.29 [0.0009]	3.13[0.9258]
area under ROC curve	0.75	0.74

Table A.4.4 Colombia: Innovation Output Determinants

	Product innovation	Process innovation	IPR innovation	IPR innovation 2
Constant	-1.03	-0.95	-2.07	-2.17
Firms characteristics				
Firm size (ln employees)	**0.20**	**0.17**	**0.06**	**0.07**
Capital location	**0.15**	0.02	0.01	0.03
Absorption capacity				
R&D department	**0.46**	**0.27**	**0.40**	**0.36**
Human capital				
Share of employee with tertiary	**0.35**	**0.21**	0.08	
Share of employee with high education				**0.53**
Share of employee with secondary education	**0.14**	0.07	0.07	0.13
Collaboration on innovation				
Universities	**0.44**	0.17	**0.51**	**0.50**
Research centres (private and public)	**0.58**	**0.41**	**0.57**	**0.58**
Suppliers	**0.50**	**0.69**	0.23	0.26
Internal	0.39	0.30	0.40	0.34
Other firms	0.20	0.09	0.12	0.11
Training and Re-education				
Innovation and development	**0.48**	**0.55**	**0.14**	***0.13***
Organizational	**0.26**	**0.22**	0.13	0.12
Management	-0.07	***-0.13***	-0.04	-0.05
Observations	6212	6212	6212	6188
Log likelihood (χ^2)	-3872.58	-3958.72	-1221.09	-1221.09
R^2 (Pseudo)	0.10	0.08	0.05	0.05
Test				
Hosmer-Lemeshow chi2(8)	51.59 [0.0000]	55.76[0.0000]	8.26 [0.4084]	8.84 [0.4004]
area under ROC curve	0.72	0.69	0.67	0.67

Note The model IPR innovation 2 includes share of employees with high education as explanatory variable

Table A.4.5 Marginal Effects for Chilean Model.

	Patents	**Product innovation**	**Process innovation**
Firm Characteristics			
Export active	***0.05***	0.01	**0.16**
Firm age (ln age)	**0.05**	***0.04***	0.00
Firm size (ln size)	0.00	-0.03	***0.05***
Collaboration on innovation with			
Universities	**0.37**	**0.29**	0.19
Consultants	-0.02	0.12	0.16
Suppliers	**0.09**	**0.31**	**0.35**
Other fimrs	0.01	-0.01	0.09
Absorptive capacity			
R&D department	**0.08**	**0.19**	0.12
Innovation intensity	0.00	**0.03**	**0.07**
Investment in innovation education	**0.09**	**0.27**	**0.23**
Permanent innovation activities	-0.01	**0.28**	**0.32**
Human capital			
Knowledge of managers rated high	-0.04	-0.05	-0.01
Knowledge of supervisors rated high	***0.04***	**0.14**	**0.16**
Knowledge of workers rated high	**0.07**	**-0.18**	**-0.22**
Managers education and training rated high	-0.04	**0.20**	-0.04
Supervisors education and training rated high	0.01	-0.08	0.08
Worker education and training rated high	-0.04	0.10	0.08
Sector – Manufacturing			
Food, Beverages and Tobacco	Ref	Ref	Ref
Textile, Wearing Apparel and Leather	0.00	0.04	0.00
Wood and wood products, furniture	**0.10**	***-0.14***	0.06
Paper, printing and publishing	0.04	-0.05	0.02
Chemicals, petroleum, coal, rubber and plastics	0.02	0.00	0.02
Non metallic mineral products, except products of petroleum and coal	-0.04	**0.27**	0.03
Basic metal industry	0.05	***-0.30***	-0.04
Fabricated metal products, machinery and equipment	-0.02	0.01	0.04
Other manufacturing industries	-0.01	-0.12	-0.25
Observations	4570	4570	4570
R2	0.25	0.33	0.37
Log Likelihood	-164	-311	-295

Note: Bold is denoting significance in a 5% level. Bold + Italic denotes significance in a 10% level.

Table A.4.6 Marginal Effects for Colombian Model.

	Product innovation	**Process innovation**	**IPR**
Firms characteristics			
Firm size (ln #employees)	**0.08**	**0.17**	**0.06**
Capital location	**0.06**	0.02	0.01
R&D department	**0.18**	**0.27**	**0.40**
Human capital			
Share of employee with tertiary	**0.35**	**0.21**	0.08
Share of employee with secondary	**0.14**	0.07	0.07
Collaboration on innovation			
Universities	**0.44**	0.17	**0.51**
Research centers (private and public)	**0.58**	**0.41**	**0.57**
Suppliers	**0.50**	**0.69**	0.23
Internal	0.39	0.30	0.40
Other firms	0.20	0.09	0.12
Training and Re-education			
Innovation and development	**0.48**	**0.55**	**0.14**
Organizational	**0.26**	**0.22**	0.13
Management	-0.07	***-0.13***	-0.04
Observations	6212	6212	6212

ANNEX 5: CONCERNS REGARDING DATA

Chilean survey

One of the main problems in empirically modeling and analyzing the data from Chile is the nature of the data, which is mainly perceptional. This annex discusses concerns about the data focusing on possible pitfalls in the analysis and the conclusions. An additional concern is the possible inconsistency of the data. Finally there is a problem of self-selection in the models, since the empirical models use data from all the manufacturing firms when modeling the determinants of innovative outcome.

The data is mainly perceptional. There are concerns about perceptional data as they are reflections of the respondent's subjective views. One concern regards innovation sales, particularly in innovation intensive sub-sectors of the manufacturing industry, where the percentages of sales allocated to innovative products or processes may not be consistent throughout the sample.

Problems of comparing responses across the sample. The importance of introducing a new product or process may also be different throughout the data. Different firms may attribute different importance to a new product or a new process if they are new only to the firm or new to the market. Therefore it is difficult to compare and use the information across the data.

Inconsistency in the data is also a concern. Before going deeper into a discussion about inconsistency it is important to state that the inconsistency problem is based on non-weighted data. The following states some examples of possible inconsistency in the data sample:

1. Product innovating[22] firms do not have any innovation expenses[23]
2. Firms with research and development departments do not have any research and development expenses
3. Several firms that reported having 30 percent or more of their sales come from innovation sales did not have any innovation expenses.

The data and the results/analysis from the data could improve significantly if these errors or mistakes were taken into consideration.

1. **Product innovating firms that do not have any innovation expenses.** There may be a reasonable explanation for this problem. The survey asks about product innovation within the last three years. In addition the innovation expenses, including the R&D expenditure, only concerns the year 2000 (and also a

[22] Firms defined as product innovative have responded with the answer 1 – 4 to the three questions about product innovation in the questionnaire. The questions concerns: 1) improved technique in the products, 2) products new to firm, but known to the market and 3) products new to the firm <u>and</u> to the market.

[23] Innovation expenses includes R&D expenses

prediction of the expenses in 2001). It can thus be argued that product innovation introduced in 1998 may be the outcome of investments prior to 1998. This in turn means that every product innovation claimed in the survey may not result from innovation expenditures in the year 2000. It can therefore be argued that there is no inconsistency between the two variables, and as such no further concerns about the results.

2. **R&D department, but no R&D expenditure.** This inconsistency is harder to explain. It could be argued that some firms are not sure of the exact amount of expenditure and therefore refrain from specifying the R&D expenditure. When the firms refrain from stating the expenditure the variable will be set to 0 in the survey. The following table compares whether firms have a R&D department and not any R&D expenses divided by firm size, in order to verify whether smaller firms are more likely to be present in such inconsistency.

Table A.5.1 R&D Department and R&D Expenses

R&D department	R&D expenses					
	Small firms		**Medium firms**		**Big firms**	
	No	Yes	No	Yes	No	Yes
No	177	14	129	44	107	44
Yes	5	24	11	46	16	72

Note. Small firms have less than 50 employees, medium firms have between 51 and 200 employees and big firms have more than 200 employees.

The table shows that 5 small firms, 11 medium sized firms and 16 big firms report having a R&D department but not any R&D expenditure. There is therefore no clear answer to whether it is a problem for smaller firms rather than bigger firms. Further the problem is that missing values have been valued to "0". This simplification of the information in data is a problem when trying to process the data and therefore it is hard to do any stratification or reparation of the data in order to optimize the consistency. Whether it is a problem for further analysis is also a question. It is not a considerable problem in this brief analysis, because this inconsistency does not seem to be biased toward any specific type of firm or any specific kind of variable and as such the problems may not be severe in the analyses.

3. It is hard to believe that 20 percent of the firms with 30 - 70 percent of their sales from innovation sales report no innovation expenses. For most firms it is difficult to specify their innovation or R&D expenses. This difficulty may lead to respondents which do not answer the question. When using dummy variables to categorize if a firm is innovative or not based upon positive response to innovation expenditure, this may lead to a possible bias. The bias could be skewed towards smaller firms, where the smallest firms' innovation activities will be under-estimated on average compared to bigger firms. This may lead to a bias of the analytical results in favor of bigger firms.

Discussion of perception data as opposed to objective measures. Perception data have the strength and weakness of building on perceptions of the respondent. For example, the answers may incorporate some information that would otherwise be lost, if the data were of a more objective character. By contrast, a drawback of perception data is that respondents might provide inconsistent information. Introducing a new product may have different importance for different firms or even different individual respondents, and it may not be clear whether the respondent is answering from the viewpoint of the firm or of the individual.

Even though there are some concerns about the data it is still possible to implement the models. It is however important to remember that there are these inconsistencies when reading and interpreting the results.

Colombian survey

The quality of the data of the Colombian survey seems to be very good. The consistencies across the different variables were checked and no major errors or inconsistencies were revealed. One example of the control for consistency is to control whether firms that claim that they have innovation activities or R&D activities also have expenditures on innovation and R&D respectively. This analysis did not reveal any problems.

In the description of the data 7 percent of the Colombian firms reported having R&D related expenses, but 10 percent have an R&D department. This inconsistency can be difficult to explain. The straightforward answer is that there are some Colombian firms who do not have activities in their R&D departments. A more reasonable explanation is that the investments related to the activities in the R&D department are not regarded as R&D activities, but more broadly as innovation activities. This seems to be a reasonable answer to this potential inconsistency.

An additional potential inconsistency was the sum of PhDs employed in the private sector, which was reported to be 4680. It is a high number and compared to the total of people with a master degree (678) seems greatly exaggerated. A closer look at the data revealed four firms reported 99 PhDs in each department but were identified 99 PhDs in total. To deal with this obvious inconsistency we identify the 11 different departments and reduced the number of PhDs to zero for each individual department, whilst leaving the number of PhDs in the firm as a whole unchanged. As a result the total of PhDs was reduced by 4,356 (4 times 99 times 11) leaving a total of 324 PhDs employed in the Colombian private sector. The following table provides a view of the problem with the number of PhDs. The "calculated total" is the total computed manually on basis of the information of the 11 different departments.

Table A.5.2 Number of PhDs in Each Department

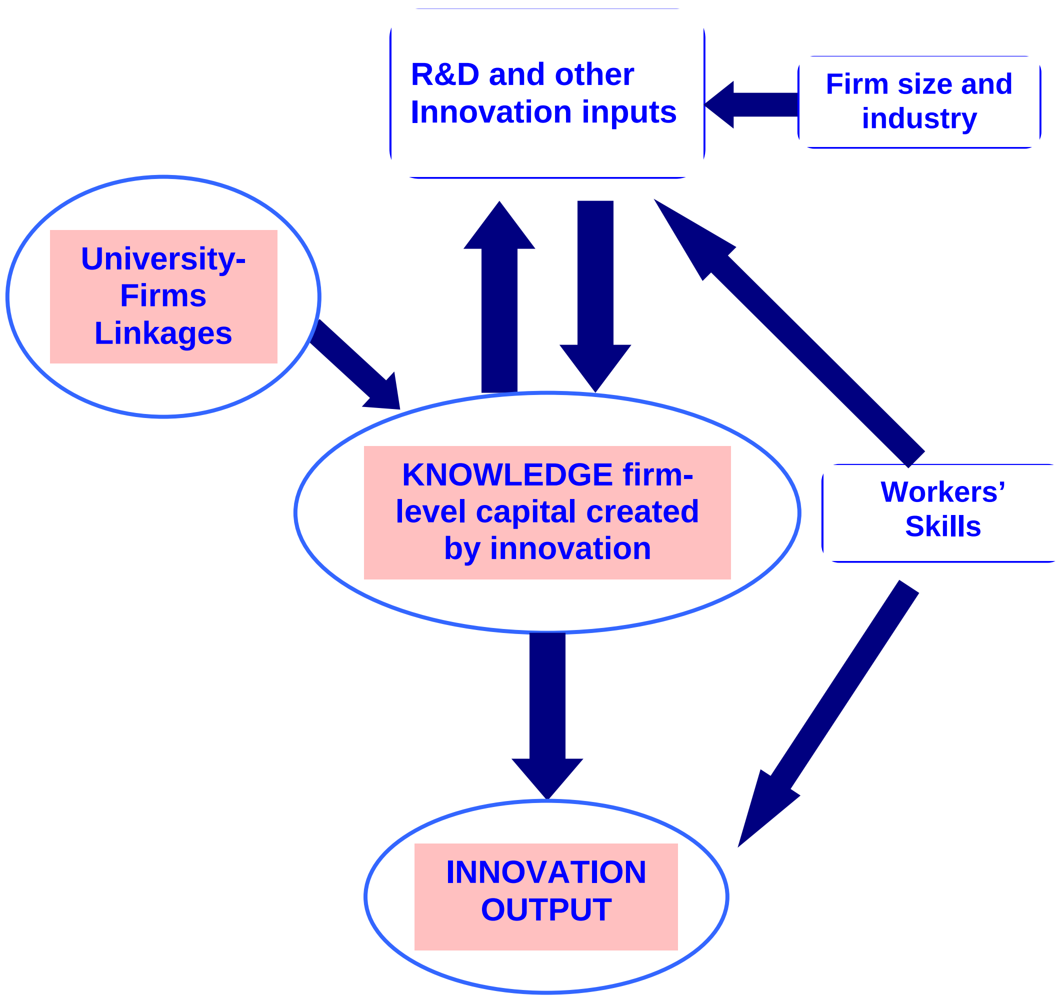
Department	Mean	Max	Min	Sum
Administration	0.09	99	0	611
Sales	0.07	99	0	436
Design	0.06	99	0	402
Engineering	0.07	99	0	407

R&D	0.07	99	0	429
Production	0.07	99	0	409
Quality test	0.06	99	0	399
Environment	0.06	99	0	396
Safety and health	0.06	99	0	397
Computers	0.06	99	0	396
Others	0.06	99	0	398
Total	0.12	99	0	720
Calculated total (excl Total)	0.75	1089	0	4680

Source: Data from the 2nd study in technological development and in innovation in Colombia 2005

To get a broader view of the content of the data please read the "Innovación y Desarrollo Tecnológico en la Industria Manufacturera Colombia 2003 – 2004" report from DANE (2005), which provides an extensive view of the data that is the foundation for this paper.

Figure 1 Main Factors Determining Firms' Innovation Output



References

Benavente. J.M.; De Mello, L. and Mulder, N. (2005) “Fostering Innovation in Chile”, OECD Economics Department Working Papers, No 454

Benavente. J.M. (2002) “The Role of Research and Innovation in Promoting Productivity in Chile”

Bosch, M., Lederman, D. and Maloney, W. (2005) “Patenting and R&D: a global view” World Bank Working Paper Series 3739

Cohen, W.M. and Levinthal, D.A. (1989) “Innovation and Learning: the Two Faces of R&D”, Economic Journal 99: 569-96

De Ferranti et al (2003) “Closing the gap in education and technology”, the World Bank

Duguet, E. (2002) “Knowledge Diffusion, technological Innovation and TFP Growth at the firm-level: evidence from French manufacturing” Economics of Innovation and New Technology, 2003, vol. 13 (1-2)

Griliches Z (1984), R&D, Patents and Productivity, University of Chicago Press

———. (1995), "R&D and Productivity: Econometric Results and Measurement Issues", in P. Stoneman, Handbook of the Economics of Innovation and Technological Change, Basil Blackwell

Gray C. (2006) Absorptive capacity, knowledge management and innovation in entrepreneurial small firms. *International Journal of Entrepreneurial Behaviour & Research*

Hall, B.H and Mairesse, J. (2006) “Empirical Studies of Innovation in the Knowledge Driven Economy”, NBER Working Paper n.12320

Holm-Nielsen, L. and Agapitova, N. (2002) “Chile’ Science, Technology and Innovation”, LCSHD Working Paper

Ledermand D. and Maloney, W. (2003) “R&D and Development” WB Working Paper Series 3024

Lundvall, B.(2007) “Higher Education, Innovation and Economic Development”, paper presented at the World Bank’s Regional Conference on Development Economics, Beijing, January 2007

F. Malerba and S. Brusoni (2007), Perspectives in Innovation, Cambridge University Press

Maloney, W.F. (2002) “Missed Opportunities. Innovation and Resource-Based Growth in Latin America” Policy Research Working Paper 2935, The World Bank

Maloney, W.F. and Rodriguez-Clare, A. (2005) “Innovation Shortfalls”, Inter-American Development Bank, Latin American research Network, Working Paper n. 543

Parisi, M.L; Schiantarelli, F. and Sembenelli, A. (2002) “Productivity, Innovation Creation and Absorption, and R&D: Micro Evidence for Italy” Working Paper in Economics, Boston College

Vestergaard, J. (2005) “Innovation and University Interaction with Industry in Colombia” Study commissioned by the World Bank

Vinding, A.L (2004) “Human Resources, Absorptive Capacity and Innovative Performance” in “Product Innovation, Interactive Learning and Economic Performance” Christensen and Lundvall, Oxford, Elsevier Ltd: 155-178

Wheeler, C.H. (2005) “Do Localization Economies Derive from Human Capital Externalities?” Working Paper 2005-015A, Federal Reserve Bank of St Louis