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Uruguayan Manufacturing Firms

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Abstract[*]

Uruguay's inability to sustain high levels of economic growth cannot be fully explained by external shocks, the prevailing institutional setting or the level of human capital accumulation. Instead, low investment in knowledge capital stands as a most likely explanation. This hypothesis is supported by empirical evidence analyzed in this study. Returns on innovation were found to be significant, promoting a non-negligible acceleration of labor productivity gains. However, the propensity to innovate and the intensity of the effort expended critically depend on the firm's already having a high internal efficiency level. As firms' behavior is differentiated depending on the type of innovation output pursued, the significantly higher frequency of processes relative to product-innovative firms is matched by the larger impact of novel processes with respect to products on labor productivity. However, the degree of novelty of process innovation is significantly inferior to that of product innovation. The research points to inadequate choices of input mixes as the underlying cause. Policy recommendations center on finding adequate channels to generate and disseminate information on the optimal input mixes depending on the type of innovation output sought.

JEL: O31, O32, D21

Keywords: Innovation input, Innovation output, Productivity growth, CDM model

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1. Introduction

The theoretical and empirical literature devoted to analyzing the constraints to growth has pointed to alternative and/or complementary explanations for describing the mechanisms at work. Some of the causes that have gained consensus are linked to low human capital endowments, insufficient provision of public goods, financial market failures, and shortcomings in the regulatory framework or overall business environment.

In the case of Uruguay, the growth rates registered between 1960 and 2000 are far from those expected at the technological frontier. Focusing on the 1990s, the observed idleness may be linked to the extremely low level of investment demand that, in turn, is not caused by the existence of human capital restrictions or an inadequate institutional framework (Bértola et al., 2005; Hausmann et al., 2005). Conversely, it may be argued that the returns on capital are not high enough due to macroeconomic factors, such as the high degree of volatility of public policies, or to the sensitivity of the economy to its neighbors' economic performance. Indeed, the notable increase in the investment rates during the last five years was matched by a reduction of Uruguay's dependence on Argentine and Brazilian demand due to the diversification of its exports and an increase in public investment. Although growth rates have evolved accordingly, attaining much higher levels than in the past, there is still a long way to go.

A different and complementary view relates to the innovation behavior of agents as a key explanation of the sluggish dynamism of private investment. Resources invested in R&D and other innovation activities within existing firms have been scarce, while so-called self-discovery efforts—that is, efforts devoted to finding new activities with a potentially high level of profitability—are not yet widespread. Although this behavior may derive from agents being risk averse, it is also probable that financial assistance is insufficient, that information channels are inadequate, and/or that public policies directly supporting innovation activities are non-optimal. Consequently, the generation of incentives to increase R&D and other innovation strategies in order to allow for a better performance in the future has become a growing concern for the country. Such concerns have been reflected in the creation of institutions devoted to the analysis of the expected impact of innovation on different areas. Furthermore, in 2005 the new government created the Ministerial Bureau for Innovation, comprising four ministries (Industry and Energy; Agriculture and Livestock; Economy and Finance; Education and Culture) which interact with the Office of Budget and Planning to promote innovation. One particular goal pursued is the definition of general policies regarding innovation and scientific research, in line with those of the National Innovation System.[1] The current institutional framework is such that the analysis of the innovation mechanisms and the required incentives are mostly in place. The research summarized below attempts to make a contribution to this effort.

2. Determinants of Innovation and its Impact on Productivity Growth

2.1. Motivation and Previous Studies

The literature on the effects of innovation on economic growth may be traced back to 1957 to the work done by Solow. The main obstacles faced by researchers at the time were linked to the measurement of technical progress and were surmounted by estimating it as a residual factor. Later on, researchers have used level of expenditure devoted to R&D or as a percentage of total revenue as a proxy for innovation. The latter was used as a proxy variable of an additional production factor so that its coefficient in a total factor productivity equation would account for the returns on innovation (see Mairesse and Sassenou, 1991).

Before the 1980s, most studies on innovation behavior and technical change used aggregated data, thus suffering from the well-known aggregation bias (Theil, 1954). Once firm-level information started to be available, the analyses switched to using microdata (see Hall and Mairesse, 2006 for an extensive survey). Further, in the late 1990s, several country studies were done using relatively more complex theoretical/methodological frameworks. Crépon et al. (1998) is one of the earliest references. Their theoretical framework was in line with that proposed by Griliches (1979) and used in Pakes and Griliches (1984).

The authors first noted that the inclusion of R&D expenditure in the productivity equation was incorrect, as the actual production factor to be taken into account should be the output that resulted from having invested in R&D instead. Under such circumstances, it became necessary to propose a way of modeling the mechanisms giving rise to the generation of the innovation output, as well as to analyze the determinants of the size of the effort devoted to it. One of the main findings of the empirical work performed under this scheme relates to its detecting the existence of significant biases in the estimated returns on innovation as reported in the previous applied literature. Soon Crépon et al. (hereafter referred to as CDM) became the most widely used

[1] In fact, the National Agency of Research and Innovation (ANII, in Spanish) was recently created to coordinate actions related to designing and implementing innovation strategies.

benchmark for subsequent research. Indeed, the CDM theoretical framework generated a unification of subsequent empirical research looking at innovation and productivity in terms of applied econometric models, enabling results to be compared across studies and between countries. Most of the studies performed for Europe, the United States, Canada, and even some Asian countries obtain results that are consistent with those of CDM in terms of finding a positive relationship between the innovation effort and the resulting innovation output, as well as between the innovation output and the firm's productivity level.[2,3]

Some research has focused attention on certain specific features of interest. This is the case of the role played by tertiary education in the generation of skills (Rao et al., 2002); the effects of having different objectives when innovating on the extent of the effort devoted to it (Tang and Lee, 2006); or the expected impacts of innovation from the perspective of multinationals (Castellani and Zanfei, 2006; Alexander et al., 1995). Another research focus is the role of process innovation versus product innovation. Lee and Kang's (2007) findings for South Korea suggest that innovative processes have a higher impact on firm productivity in the short run when compared to the impact of product innovation. This supports the model by Huergo and Jaumandreu (2004), where process innovation has an extra impact on the growth rate of productivity that, although persistent, has effects only in the short run. Some of the studies for small European countries (e.g., Czarnitzki and O'Byrnes, 2007) also find that process innovation is the main driver behind productivity growth, while product innovation has a non-significant impact. Masso and Vahter (2008) further find that product and process innovation have different effects on productivity depending on the underlying macroeconomic conditions.

Certain studies have attempted to compare the results for different countries, as is the case of Griffith et al. (2006) using French, German, Spanish, and British data, and Janz et al. (2004), who pool German and Swedish data in a common regression to compare the links between innovation and productivity in those two countries, among others. Their results suggest that

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[2] See Arundel *et al*. (2003) for an extensive survey.

[3] Some of the recent European studies that have used firm level data to analyze innovation behavior within the CDM framework are Llorca-Vivero (2002); Lööf and Heshmati (2002); Griffith *at al*. (2004; 2006); Janz *et al*. (2004); Van Leeuwen and Klomp (2006); Mohnen *et al*. (2006); Castellani and Zanfei (2007); Czarnitzki and O'Byrnes (2007); and Cainelli (2008). Further, Stoevsky (2005); Roud (2007); and Masso and Vahter (2008) use the Community Innovation Surveys to analyze the applicability of the CDM framework in Eastern European countries – Bulgaria, Russia and Estonia, respectively. Among the most recent Asian country studies – performed for China, South Korea, Taiwan, Japan, and others – it is worth mentioning Chang and Robin (2004); Tsai and Wang (2004); Jefferson *et al*. (2006); and Lee and Kang (2007), while for US and Canada the work by Los and Verspagen (2000); Rao *et al*. (2002); Tang and Lee (2006) are worth to cite.

although there are certain country-specific effects affecting the non-core parameters, the main estimates for the elasticities of interest in both the productivity and the input-output equations do not significantly differ among developed countries.

Although it has recently been catching up, the research on innovation impacts on firm performance in Latin America is still scarce. Notable exceptions are Chudnovsky et al. (2006) and López and Orlicki (2006) for Argentina; Cassiolato et al. (2003) and Goedhuys (2007) for Brazil; Benavente (2004; 2006) for Chile; Hernández (2005) for Colombia; and Pérez et al. (2005) for Mexico.[4] The results obtained, however, are not always in line with those of CDM, as in most of these studies no significant relationship is found between innovation input and output, or between innovation output and labor productivity. On the contrary, Raffo et al. (2007) do find significant effects on both the input-output and the productivity equations for Argentina, Brazil, and Mexico. Further findings relate to the negative effects of firms' insufficient interaction with NIS agents, while their having links with international partners, as is the case of foreign-owned o firms and of those belonging to an international group, promotes innovation activities.

While no research along these lines has yet been done for Uruguay, some evidence of the extent of innovation efforts can be found in Hausmann et al. (2005) and in Hall and Maffioli (2008). Both papers conclude, although with some mixed evidence in the latter case, that Uruguayan performance is far from the expected standards regarding innovation practices, while the absence of economic incentives may be one of its main underlying causes. Arocena and Sutz (2008) arrive at similar conclusions regarding the size and evolution of the innovation intensity gap between Uruguay and the most developed countries, while Bianchi and Gras (2005) also point in that direction. Further, Bianchi et al. (2008) analyze some of the distinct characteristics of firms undertaking innovation that may explain the aforementioned gap, concluding that some of the factors underlying the phenomenon are linked to scarce public support, both financial and operational, and to the lack of cooperation among firms. Further, their analysis suggests that a high average technical level of the firm's workforce is one of the key requirements for successfully undertaking innovation activities in Uruguay.

The consistency of results among studies for European countries and the differing results obtained for less developed economies motivates a thorough analysis of the applicability of the

[4] A good survey on the results obtained for several Latin American countries can be found in Hall and Maffioli (2008).

CDM framework to latter, especially in the case of Latin America. One of the likely explanations is related to the use of innovative sales, the standard *proxy* for innovation output in the CDM framework, since the indicator would be less applicable in countries devoting a large extent of their innovation efforts to processes rather than in products. In order to find evidence of the mechanisms at work in the case of in Uruguay, we analyzed the innovation behavior of manufacturing firms over a ten-year period, within the CDM framework but using a different approach to define the appropriate *proxy* variable for innovation output.

2.2. Analytical Framework: The CDM Model

The work of Crépon et al. (1998) is the first formalization of the innovation behavior of firms as a multi-step decision process. An initial step in their model consists of understanding the factors that determine the decision of engaging in innovation activities, assumed related to firm and market characteristics. As such, not all firms are expected to innovate, the rationale giving support to the stylized fact revealing that there are a large number of non-innovative firms in all economies.

Once a firm has decided to innovate, it has to decide on the amount of resources to be devoted to innovation activities, assumed to be exogenously set. As such, the CDM proposal is that the innovation effort does not result from the optimization of the level of expenditure needed for achieving certain goals in terms of firm performance and/or investment profitability; rather, it is associated with the prevailing macroeconomic conditions, market structure and firms' characteristics. The assumption is compatible with various alternative strategies, as is the case of firms that innovate in order to comply with health, safety, and environmental regulations or when seeking to adhere to certain national/international standards in terms of product and process quality. Moreover, the exogeneity of the innovation effort may well be a sensible hypothesis when the decision is not even taken by the firm itself but rather by related agents, such as the parent company of which the firm is a local branch or subsidiary.

Under the assumption that there is only one innovation input—R&D—once having decided on the amount to be spent, the model suggests a feasible mechanism, the so called *knowledge production function,* by which the innovation input is transformed into an innovation output, that is in turn assumed to alter the firm's technology of production and becoming an additional production factor. Given the new production technology, the observed level and rate of growth of productivity and most other indicators of the firm's economic performance should vary accordingly.

The basic structure of the CDM model described above may be formalized specifying three distinct blocs of equations that reflect the firm's decision to pursue innovation activities and the amount to be devoted to them; the mechanism through which inputs are transformed into an innovative output; and the resulting impact of the innovation output on the firm's performance. These three stages are below formalized as in the original CDM paper.

Let g^*_i be a latent variable denoting firm i's propensity to innovate and C^*_i a certain threshold interpretable as a decision criterion to innovate. Whenever g^*_i exceeds C^*_i it is possible to observe innovation activities performed by firm i, which are denoted as g_i. Vector $\boldsymbol{X}_{0i}$ includes firm and market characteristics assumed to be drivers of the decision to pursue innovation activities. It is possible to formalize the rationale by means of equation (CDM_1). For the observable g_i, one may also observe the size or intensity of the innovation effort—k_i—that is assumed to depend on firm, market, and macroeconomic characteristics denoted by $\boldsymbol{X}_{1i}$ in equation (CDM_2). A second stage involves determining the input-output equations depending on the type of theoretical model used to explain the firm's knowledge production function. The knowledge production function proposed in Crépon et al. (1998), which may or may not be linear, is stated in (CDM_3) as a one-factor production function—the previously estimated expenditure on R&D. It is assumed that t_i, the value of innovation output, also depends on a set of firm, market, and macroeconomic characteristics included below in vector $\boldsymbol{X}_{2i}$. Finally, considering t as the current investment that linearly increases knowledge-capital endowment, and that the role of knowledge-capital is analogous to that of any production factor, one may proxy the effects of innovation on the level or the rate of growth of labor productivity (q_i) by estimating equation (CDM_4). Other production factors that enter the equation as a ratio on labor are gathered in vector $\boldsymbol{Z}_i$—physical capital, labor and eventually intermediate consumption—while specificities that are assumed to have a scale effect on the firm's productivity level or rate of growth are included in $\boldsymbol{X}_{3i}$:

$$g_i^* \geq C^*_i \;\Rightarrow\; g_i = \boldsymbol{X}_{0i}\boldsymbol{\beta}_0 \quad ; \; g_i^* < C^*_i \;\Rightarrow\; g_i = 0 \qquad (CDM_1)$$

$$g_i \neq 0 \;\Rightarrow\; k_i = \boldsymbol{X}_{1i}\boldsymbol{\beta}_1 \quad ; \; g_i = 0 \;\Rightarrow\; k_i = 0 \qquad (CDM_2)$$

$$k_i \neq 0 \;\; (g_i \neq 0) \;\Rightarrow\; t_i = k_i\, \alpha + \boldsymbol{X}_{2i}\boldsymbol{\beta}_2 \;\; ; \; k_i = 0 \;\; (g_i = 0) \;\Rightarrow\; t_i = 0 \qquad (CDM_3)$$

$$lnq_i = \sigma\sum t_i + ln\boldsymbol{Z}_i\boldsymbol{\lambda} + \boldsymbol{X}_{3i}\boldsymbol{\beta}_3 \quad \text{or else: } \Delta lnq_i = \sigma t_i + \boldsymbol{\lambda}'\Delta ln\boldsymbol{Z}_i + \boldsymbol{\beta}'_3\Delta\boldsymbol{X}_{3i} \qquad (CDM_4)$$

2.3 Review of the Empirical Implementation of the CDM Model

The applied literature using the CDM model as a benchmark has generally used datasets that stem from surveys only of innovative firms, so that (CDM_2) can only be estimated for the case $g_i^* \geq C^*_{\mathrm{i}}$ for which units are observable. To take into account this restriction and hence avoid the consequent selectivity bias of estimates, the first bloc has to be modeled as a generalized Tobit. When information for non-innovative firms is available from alternative sources or by survey design, equation (CDM_1) can be ignored. Under such circumstances, the analysis of the determinants of the decision to innovate is embedded in (CDM_2), due to the fact that firms with nil expenditure correspond to non-innovative units, so that the model is specified conditional on the decision whether or not to innovate.

The empirical implementation of the theoretical CDM model has encountered several obstacles that have frequently been sorted out by using highly simplified estimable models. As such, the analysis of firms' innovation behavior and the potential policy recommendations on the matter are impoverished.

A first issue refers to neglecting the existence of other innovation inputs apart from R&D activities, a topic theoretically discussed in the CDM paper. It may be argued that accumulated R&D constitutes the innovation input *par excellence*, but engineering design or income spillovers are also typically knowledge-driven inputs. Further, as documented for example by Denison (1985), R&D can only account for a small portion of the innovative practices. The introduction of novel IT tools, on the other hand, or the purchase of certain physical capital, may be considered as investments in innovation inputs of an intrinsically different nature than research activities, but they also lead to an innovation output. Including other innovation inputs in the CDM model forces the specification of a distributional procedure by which the resources invested in innovation are allocated among the distinct inputs. Further, since it is most unlikely that a unique mix of innovation inputs generates any type of innovation output, a further challenge relates to the specification of the path through which innovation inputs are combined.[5]

The exclusion of other innovation inputs from the CDM model leads to undesirable consequences in terms of the empirically estimated relationships, while if complementarities

[5] For example, introducing new machinery would generally allow for producing a different type of products or to implement a novel production process. Further, in generating a different modality of production, its acquisition might imply that some training has to be undertaken by workers; or that engineering design is needed; while at times it also poses new challenges to the firm that have to be faced by further investment in R&D.

exist, adding up the resources spent in different inputs would also be an incorrect measure of the resulting overall innovation input and its role in generating an innovation output. The empirical consequences are yet to be quantified, so that it is highly desirable to start performing some research on the topic, despite the methodological difficulties it poses. We do not address the issue in depth in this paper, as it lies beyond the scope of the project. However, we include an innovation input concentration indicator aiming at weighting the size of the effort by the degree to which innovation expenditure is diversified and concentrated among the different types of innovation input. In order to account for differences in the prices of the diverse innovation inputs, we include binary variables stating whether each type of input has been acquired.

A second shortcoming of empirical CDM models arises from the non-availability of the necessary data for the specification and estimation of the knowledge-capital production function as defined in the original CDM paper. A strand of the literature has *proxied* investment in knowledge capital (t_i) by the ratio of innovation to total sales, assuming that knowledge capital is generated in a linear way through R&D expenditure with a nil depreciation rate.[6] Alternatively, researchers have empirically skipped the step of specifying an equation explaining how inputs are transformed into output, substituting it by modeling the odds of obtaining an innovation output conditional on the resources invested in innovation inputs.[7]

The analysis of the effects of innovation output on the performance of firms has been mostly studied in terms of its impact on labor productivity, as reflected by (CDM_4). Given the above-stated obstacles linked to correctly measuring innovation output, i.e., knowledge capital, researchers have included the predicted probability of obtaining an innovation output in the productivity equation. In doing so, the impact of innovation output on the firm's production technology is reflected only as a scale effect. If (CDM_3) is estimated using the share of innovative sales as a *proxy* variable for generated knowledge-capital, (CDM_4) can only be specified in terms of the rate of growth of productivity. Although the strategy allows for quantifying marginal effects of the innovation output on firm performance, the approximation is useful only when obtaining innovative products, thus neglecting the role played by innovative processes. The restriction may not be substantially binding for most highly developed countries in which new

[6] See, e.g., Mairesse and Sassenou (1991) and Crépon et al. (1998).

[7] This is implemented by means of using a binary variable accounting for the firm having or not obtained an innovation output.

products may be the focus of innovative practices,[8] but it undoubtedly restrains the analysis in less developed or small economies. Furthermore, firms should not be expected to display uniform innovation behavior along the business cycle, since process innovation is a widespread practice to reduce costs when faced with economic recessions even for firms in developed countries.

As of today, whenever innovative processes have been considered explicitly in the production function, they have been included as a scale effect since their role has been *proxied* by means of a binary variable. However, there are no reasons to assume that new production processes or innovative organizational designs and commercialization strategies have no impact on the pre-existing mix of production factors. An additional undesired consequence of omitting process innovation, or of restricting its impact to scale effects, when included in the model using the share of innovative sales as a proxy variable, refers to the likely overestimation of the elasticity of product innovation, as it might actually be capturing the effects of both types of innovation output on total production. In that case, conclusions on the impact of one specific type of innovation output on firm performance would be under or over-estimated.

3. Characteristics of the Information Set[9]

3.1. The Sample

Data used stem from the matching of the three Innovation Surveys (IS) performed in 1998-2000, 2001-2003, and 2004-2006 and the Annual Economic Activity Surveys (EAS) in 1998-2006.[10] The same sampling model was used in both surveys, so that they report information on the same

[8] An exception can be found, e.g., in Czarnitzki and O'Byrnes (2007).

[9] The data referring to innovation activities of manufacturing firms has not been public until now. We were able to obtain access to it only because of the support we received from Fernando Amestoy, Executive Manager of the National Agency of Research and Innovation (ANII); Omar Macadar, Director of the Agency of Science and Technology for Development (DiCyT); Alicia Melgar, Director of the Institute of Statistics (INE); and Alvaro Fuentes, Head of the Statistics Division at INE. Moreover, because of our joint actions, a formal mechanism was designed for allowing the use of the data sets by individual researchers and research institutions from now on. We also want to pose especial emphasis on the invaluable help of Griselda Charlo, Head of the Annual Activity Survey at the INE, without the help of whom many of our analyses would not have been possible. She not only provided us with unusual celerity all the Economic Activity Survey data, but also gave us advice and information unavailable elsewhere. Finally, we want to thank Nicolás Mazón at the INE and Ximena Usher at the ANII for their assistance in clarifying many of our queries when checking on the quality and consistency of the micro data.

[10] For that reason, we will treat the data as three points in time, most variables in the survey referring either to the last year or to the whole three-year period.

units.[11] The design of the Innovation Surveys follows the recommendations included in the Bogotá Handbook, rendering the methodology used consistent with the guidelines stated in the Oslo and Frascati Handbooks.

The samples are built in such a way that all establishments with more than 49 workers are of mandatory inclusion. Two additional strata are defined—fewer than 19 workers and 20 to 49 employees. Units within these classes are selected using simple random sampling within each economic sector at the ISIC 2-digit level up to 2005. Since then, random strata are defined as those units with fewer than 50 workers within each economic sector at the ISIC 4-digit level. Further, several units that would be chosen randomly given the size of their workforce are nonetheless certainty units due to the need of guaranteeing representativeness of the strata for the EAS. The response rate is always higher than 90 percent (generally above 95 percent), with the exception of the stratum of the smallest firms in the first survey (88 percent).[12] We work with sample data given the available sampling expanding factors reflecting employment and growth dynamics, but not necessarily the innovation behavior of manufacturing firms.[13]

The number of firms finally included in the samples used in 1998-2000, 2001-2003, and 2004-2006 were 761, 814 and 839, respectively.[14,15] We further reduced the sample sizes by eliminating those firms with five or fewer workers throughout the period because we considered their data not fully reliable (54, 21, and 25 cases in each survey, respectively).[16] We thus ended with a benchmark dataset of 707, 793, and 814 units of observation in each respective period. These sets were further reduced keeping only the firms for which data are available throughout

[11] The innovation surveys were carried out by the National Institute of Statistics (INE), under request of the Agency of Science and Technology for Development (DiCyT) up to 2004 and of the National Agency of Research and Innovation (ANII) since then.

[12] "Encuesta de Actividades de Innovación 1998-2000", DiNaCyT (currently named DiCyT), INE; "Encuesta de Actividades de Innovación 2001-2003", DiCyT, INE; "Encuesta de Actividades de Innovación 2004-2006", ANII, INE.

[13] This hypothesis was confirmed by Susana Picardo, who was in charge of the Annual Industrial Survey (afterwards substituted by the Annual Economic Activity Survey) in 1998. She further pointed out that this was in fact a key issue largely discussed before conducting the Innovation Survey, given the existing restrictions preventing the construction of a new sample.

[14] The total number of firms in the 1998-2000 survey was 762 according to official publications. However, one unit had missing values in all its observations and was hence dropped out of our study.

[15] In spite of the relatively small number of observations with respect to figures that are generally found in international studies, the sample is quite large relative to the small size of the Uruguayan economy. We also consider its size adequate for deriving robust inferences based on it.

[16] We base the conclusion on the data not passing most of our quality and consistency checks.

the 10 years—that is, ignoring units that were not included in all three surveys.[17] The final dataset consists of 1,482 observations corresponding to 494 firms. The strategy aims at granting meaning to the time comparison of the samples, as well as allowing for some comparison of firms' behavior by size, as explained below.

Given the design of the sample, the descriptive analysis is biased towards the behavior of large firms, excluded from the balanced panel only if there is an entry or an exit, both through merger or death. Most small firms, however, may not be surveyed in the three time periods not only as the reflection of an entry or an exit, but also because of not being selected in prior or subsequent stratified sampling processes.[18]

In order to simplify the analysis, and taking into account that the number of units within classes is relatively balanced, we pool the original size categories into four strata—19 or fewer, 20 to 49, 50 to 149, and 150 or more workers, so that the two upper classes are actually the universe of firms operating in the 10-year period. Analogously, we classify firms in 12 economic activities according to the ISIC Revision 3 classification.[19]

Most of the research performed on innovation behavior in Uruguay has used the information reported by manufacturing firms included in the Economic Activity Survey and hence in the Innovation Survey. Inference on the innovative behavior of the population, however, is not possible since no expanding factors have been built in to guarantee the representativeness of the sample. As such, the validity of the conclusions drawn should be limited to the subset of firms analyzed. A further issue that invalidates some of the results reported in the literature is that the same weight was assigned to all of the firms in the sample. However, in pooling units of

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[17] In doing so, we are excluding the possibility of analyzing the effects of innovation practices on the firms' life cycle for those units that are of mandatory inclusion. In the case of firms belonging to the less-than-50 workers strata, however, the exclusion of units may respond to other reasons related to the sampling process, hence not necessarily reflecting an entry or an exit.

[18] Between 1998 and 2000, the sample used in all manufacturing surveys was obtained from the 1997 Economic Census. The change in the classification of economic activities in sectors according to the ISIC, Revision 3, forced a correction of the sample in 2001. However, the financial breakdown of 2002 implied such a high rate of bankruptcy among firms, that the existing sample became useless. Moreover, it was not possible by then to assert with an adequate degree of confidence neither the magnitude of the adverse effects nor their probable duration in time. In order to guarantee the representativeness of the samples used under any future scenario, the Institute of Statistics decided to update the sample yearly, starting in 2003. Consequently, units included by stratified sampling in the last two surveys may come in and out of the sample more frequently than before, despite not having exited the activity. Another consequence of the 2002 negative shock that is worth noting is that many firms started diversifying their production as a means of raising their odds of surviving. Hence, many units may answer the surveys classified in a distinct economic activity depending on the time-period.

[19] Namely, Food; Beverages & Tobacco; Textiles; Wood; Printing; Chemical Products; Petroleum; Plastic & Rubber; Non-metallic Minerals; Metal Products; Equipment & Machinery; Other manufacturing industries.

mandatory inclusion with randomly selected firms, several conclusions will be biased towards the behavior of firms with specific characteristics, many of which are highly related to the dynamics of innovation, such as size. Moreover, units selected by random sampling vary from year to year, so that the substitution of innovative by non-innovative units (as well as the opposite situation) is highly likely but cannot be read as a change in the share of innovative firms, thus preventing any conclusion from being drawn on the temporal evolution unless the analysis is restricted to units included in all three surveys or to those that should be selected with certainty.

A clear-cut example of the extent to which some of the reported findings are misleading is the widely accepted stylized fact that the share and number of innovative firms have largely decreased over the last decade to around 20 percent. However, if the calculus is limited to firms of mandatory inclusion, the figure goes down to 5 percent, while if limited to units included in the three samples, it is still significantly smaller (10 percent).[20] Analogously, the propensity to innovate among size strata is also a misrepresentation of overall actual behavior, especially when pooling random and certainty units. This is because all large firms are included in the sample, while small units have a different probability of selection depending on the size stratum and economic sector.

3.2 Defining Types of Innovation Inputs and Output

Much of the empirical research excludes some of the different types of innovation input/output from their analyses for a number of reasons, such as the low frequency of firms in some categories or the lack of data. With respect to innovation output, new products and innovative productive processes is the most frequently included type, while R&D has been the preferred choice regarding innovation inputs. In the case of Uruguay, however, the frequency of firms focused in products and productive processes is too small (20 percent at most) while, although around 50 percent of firms invest in R&D, the proportion investing in training programs or in physical capital is significantly larger. We thus group the diverse available types of innovation input and output in four and two categories, respectively, balancing the inadequacy of excluding

[20] It should be noted that in the latter case the percentage reflects the behavior of a sub-sample that excludes new entries as well as exits and mergers, its own specificities most likely being associated to innovative practices. However, it still shows the significant size of the eventual biases, especially because of its similarity with the 8% decline observed among units defined as of mandatory inclusion due only to the number of employees.

any type with the econometric complexities that the original classification would introduce (Tables 1 and 2 below).[21]

Inputs are classified into R&D (both internal and external); Physical Capital, Hardware and Software (K+H+S); Training Programs, including those directed at managers (TP); and Engineering & Industrial Design, Technology Transfers, and Consultancy Services (EID+TT+CS). The output categories defined are Products accompanied or not by innovation processes of any type; and Processes Only, whether they relate to production, commercialization, or organizational practices.

Most innovative firms include K+H+S among the inputs in which to invest, TP being the second preferred choice. Investing in just one innovative input is quite rare, which points to the existence of complementarities among different types of innovation inputs. On the other hand, diverse input mixes are preferred to investing in all inputs simultaneously. The latter might be due to firms having differentiated needs and/or complementarities depending on firm, sector, and macroeconomic characteristics.

Around 60 percent of Uruguayan innovative firms obtain innovative products, a figure that is much greater than expected. We found evidence showing that the percentages cited above are overestimated. On the one hand, 3 percent of firms reported having innovative sales despite the fact that they declared having innovated only in processes and were thus excluded from the set of product-innovative firms. On the other hand, according to the proportion of firms reporting innovative sales, product innovation should be around 7 percent lower than the percentage resulting from merely counting the affirmative responses to the first question in the questionnaire which asks if an innovative product has been obtained or not. These 7 percent of units did not answer the additional questions on the kind of innovative product obtained; instead, they reported on the type of innovative processes they obtained in a completely consistent manner if ignoring the answer to the first question.[22] The fact that the percentage of firms that innovate only in products is only between 4 and 11 percent throughout the period further supports the hypothesis of an overestimation of product-innovative firms.

[21] We define the groupings taking into account their theoretical adequacy given the Uruguayan specificities and also that the distribution of firms in the new classes resembles the original categorization, even when classifying firms by size strata and economic sector.

[22] These inconsistencies may arise from the design of the first question since the expressions in Spanish denoting *output*; *result* and *product* are used interchangeably in Uruguay since the three may be translated as "*producto*". We did not correct the figures as we consider that the INE should intervene in the matter.

Table 1. Distribution of Firms by Innovation Input 1998-2006
(number and percentage of firms)

	1998-2000		2001-2003		2004-2006	
	N	%	N	%	N	%
Total firms	494	100	494	100	494	100
Innovative firms	333	67	270	55	244	49
R&D	182	55	142	52	106	44
K+H+S	286	86	217	80	199	82
EID+TT+CS	159	48	136	50	90	37
TP	229	69	182	67	167	69
Only R&D	5	2	10	4	8	3
Only K+H+S	46	14	36	13	41	17
Only EID+TT+CS	7	2	6	2	4	2
Only TP	10	3	16	6	14	6
All Inputs	82	25	62	23	41	17

Note: R&D refers to internal and/or external; K+H+S refer to Physical Capital and/or Hardware and/or Software; EID+TT+CS gathers Engineering & Industrial Design and/or Technology Transfers & Consultancy Services; TP includes both management oriented and employees training programs.
Source: Authors' calculations based on Innovation Surveys 1998-00; 2001-03, 2004-06; ANII/DiCyT /INE.

Process innovation is the most frequent type of innovation output obtained, as around 94 percent of firms innovate in at least one process.[23] The figures are still high if differentiating among types of process innovations, production processes being the category with the highest proportion of firms (80 percent on average). Conversely, the percentages are low when restricted to just one type of process for all three categories, as well as when looking at the standard combination of obtaining product and productive process innovation (TPP) exclusively. Analogously, it is most uncommon to find firms engaging in product innovation without implementing new production *and* non-technological procedures. Thus, it is possible to state that Uruguayan firms display an innovation strategy that generally combines novel production processes with either new commercialization practices or changes in the firm's organizational structure.

[23] The result is consistent with the stylized fact reported in the applied literature regarding the innovation behavior of firms in non-developed countries relative to that generally seen in central economies.

Table 2. Distribution of Firms by Innovation Output 1998-2006
(number and percentage of firms)

	1998-2000		2001-2003		2004-2006	
	N	%	N	%	N	%
Innovative firms	333	100	270	100	244	100
Firms with innovative output	322	97	266	99	240	98
Production Processes	268	83	224	84	171	71
Organizational Processes	212	66	182	68	104	43
Commercialization Processes	170	53	145	55	57	24
Processes	309	96	253	95	214	89
Products	206	64	172	64	136	57
Processes Only	116	36	94	36	104	43
Production Processes Only	34	10	20	7	43	18
Non- Production Processes Only	26	8	24	9	32	13
Products Only	13	4	13	5	26	11
Products & Production Processes	34	10	36	13	44	20
Products & Non-Production Processes	15	5	5	2	11	5
All types of Outputs	107	33	90	34	27	11

Note: "Production Processes" refers to new or improved productive methods. "Processes Only" refers to innovating in at least one process and not in products, while the category "Processes" include firms that innovate in at least one process, regardless of whether they also innovate in products. "Products" includes all firms innovating in products only and those that also innovate in at least one process. Thus, the categories "Processes Only" and "Products" add up to 100 percent, as do the categories 'Processes' and 'Products Only'.
Source: Authors' calculations based on data from Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE.

3.3 Who are the Innovative Firms and What Output Do they Obtain?

The comparative statistics of the behavior of firms regarding innovative input and output in Tables 1 and 2 are not clear-cut, partly due to the data referring to both random and certainty units indiscriminately. However, the information does reveal that the rate of success among innovative firms is stable throughout the period and not influenced by the economic cycle.[24] Most firms that invest in innovation inputs are able to get an innovation output within a three-year period. Between 97 and 99 percent of innovative firms report having obtained results in the three surveys. Although these figures could include a current innovation output that is related to having invested in innovation inputs in previous periods, this is not the case for the samples analyzed.

[24] When referring to "economic cycle" we consider the first period (1998 to 2000) as a slowdown in the economy hitting bottom in 2002, the upswing starting in 2004. We confirm these stages by estimating a moving-average of the growth rate along a three-year period centered in each year.

The proportion of firms reporting results from investing in each innovation input in the corresponding three-year period is always approximately 90 percent.[25] Hence, the input-output mechanisms may be analyzed within each survey.

The negative time trend observed for both the number and the share of innovative firms cannot be taken as reflecting the overall evolution of the population, since it is mostly driven by small firms, as can be readily seen in Table 3.

Table 3. Distribution of Firms by Innovative Behavior and Output According to Size 1998-2006
(number and percentage firms)

	1998-2000				2001-2003				2004-2006			
Firms	**Total**		**Innovative**		**Total**		**Innovative**		**Total**		**Innovative**	
	N	%	N	%	N	%	N	%	N	%	N	%
Total	494	100	333	67	494	100	270	55	494	100	244	49
19 or fewer	77	16	30	9	92	19	26	10	86	17	14	6
20 - 49	153	31	95	29	177	36	89	33	139	28	55	23
50 - 149	173	35	129	39	147	30	92	34	167	34	99	41
150 or more	91	18	79	24	78	16	63	23	102	21	76	31
Inn. Output	**Products**		**Only Processes**		**Products**		**Only Processes**		**Products**		**Only Processes**	
	N	%	N	%	N	%	N	%	N	%	N	%
Total	206	77	116	23	172	64	94	36	136	55	104	45
19 or fewer	23	17	5	4	16	12	10	11	8	6	5	5
20 - 49	60	44	31	27	53	39	34	36	28	21	25	24
50 - 149	74	54	52	45	61	45	31	33	58	43	41	39
150 or more	49	36	28	24	42	31	19	20	42	31	33	32

Source: Authors' calculations based on data from Innovation Surveys 1998-00; 2001-03, 2004-06; ANII/DiCyT/INE.

These observations are made within the context of a change in the size distribution of the subset of firms under study, revealing that the strategy regarding innovation has a role to play in the survival odds of Uruguayan firms. The proportion of large firms in the total innovative group goes up slightly more than the proportion of large units among total firms, reflecting the positive association between innovation propensity and size—a sensible fact since large firms have a less

[25] These figures are obtained by counting the positive answers to the question "Have you obtained results from having invested in... (each innovative input)?"

effective constraint for spending on innovation inputs. The relation is non-linear, with the maximum attained in the 50-149 size strata, in line with the composition of firms by size.

The above-described evolution is also linked to the type of output obtained. Firms innovating only in processes increase their share substantially (from 23 to 45 percent of firms obtaining an innovation output), so that the decrease in innovative firms is driven by product innovation units. Although firms of all sizes behave similarly, the time trend towards focusing only on innovation processes was led by the largest units after the 2002 crisis. Large firms are also the core of those that innovate with respect to the international market. This pattern is not affected by the economic cycle. On the contrary, when restricted to firm and local market innovation output, the non-linear relation with the maximum in the 50 to 149 employees stratum reappears (Table 4).

Table 4. Innovative Firms by Size and Relevance of Innovation Output 2000-2006
(percentage of firms)

Relevance of Output		19 & less	20-49	50-149	150 & more
Firm Only	**2000**	10	33	34	22
	2003	9	30	37	24
	2006	7	24	38	31
Local Market	**2000**	8	36	39	17
	2003	11	26	36	27
	2006	8	22	38	32
International Market	**2000**	6	26	23	45
	2003	3	10	35	52
	2006	5	5	43	46

Source: Authors' calculations based on Innovation Surveys 1998-00; 2001-03, 2004-06; ANII/DiCyT /INE.

Most innovative firms are domestically owned units, although their share steadily diminishes over time (Table 5). The trend is mostly driven by firms innovating in processes, revealing that non-national firms are progressively substituting product with process innovation, given the data reported in Table 3. Innovative firms are evenly distributed according to whether or not they export, a pattern that does not change over the 10-year period. However, when disaggregated by the national or foreign origin of their capital, this pattern is reproduced only for national firms. The share of exporting innovative firms is significantly larger than that of non-exporting units among foreign companies and increasing in time if product innovative, while the pattern for non-national units innovating in processes is anti-cyclical.

Table 5. Distribution of Firms by Innovative Output and Firm Characteristics 1998-2006
(percentage of firms)

Output		2000			2003			2006		
		Small	**Large**	**Total**	**Small**	**Large**	**Total**	**Small**	**Large**	**Total**
National Capital	**Exporting**	23	77	55	29	71	56	21	79	56
	Non-exporting	60	40	45	71	29	44	47	53	44
	Total	25	60	85	33	53	81	27	67	78
Non-national Capital	**Exporting**	36	64	81	41	59	86	31	69	79
	Non-exporting	19	81	19	21	79	14	14	86	21
	Total	37	63	15	42	58	19	27	73	22
Total	**Exporting**	23	77	50	17	83	48	17	83	48
	Non-exporting	57	43	50	69	31	52	45	55	52
	Total	37	63	100	43	57	100	28	72	100
Products										
National Capital	**Exporting**	21	79	58	20	80	62	20	80	61
	Non-exporting	38	62	42	38	62	38	32	68	39
	Total	30	70	85	30	70	83	25	75	76
Non-national Capital	**Exporting**	20	80	80	14	86	83	25	75	84
	Non-exporting	25	75	20	38	62	17	33	64	16
	Total	27	73	15	23	77	17	27	73	24
Total	**Exporting**	26	74	58	19	81	48	17	83	48
	Non-exporting	37	63	42	41	59	52	30	70	52
	Total	29	71	64	29	71	65	21	79	57
Only Processes										
National Capital	**Exporting**	19	81	56	37	63	47	15	85	48
	Non-exporting	44	56	44	31	69	53	53	47	52
	Total	35	65	42	54	46	35	31	69	33
Non-national Capital	**Exporting**	16	84	72	27	73	90	13	87	71
	Non-exporting	36	64	28	41	59	10	32	68	29
	Total	26	74	58	35	65	65	24	76	67
Total	**Exporting**	15	85	50	24	76	48	11	89	48
	Non-exporting	33	67	50	40	60	52	32	68	52
	Total	35	65	36	54	46	35	39	61	43

Source: Own calculations based on data from Innovation Surveys 1998-00; 2001-03, 2004-06; ANII/DiCyT/INE.

Finally, innovative firms are not uniformly distributed across economic activities but rather concentrated in a few sectors—food, textiles, chemicals and machinery & equipment.[26] These four sectors account for around 75 percent of firms obtaining innovation outputs in products and processes. The figure rises to 80 percent when considering firms that innovate only in products, and drops to 70 percent when restricted to those innovating only in processes. Some characteristics shared by most firms belonging to the abovementioned sectors are that they are exporting units with export intensity of over 40 percent and owned by domestic entrepreneurs. The extent of international exposure is high for all industries and increases increasing over time. The export intensity of these firms may explain the differentiated behaviors observed throughout the economic cycle. (For a detailed discussion, see Cassoni and Ramada-Sarasola, 2009a).

3.4 Innovation Input Mix and Size of the Innovation Effort

A considerable number of innovative firms invest in all four categories of innovation inputs as defined here, while the percentage of firms investing in only one input is negligible, except in the case of physical capital andhardware and software. Preferred choices are not tightly linked to the stage of the business cycle, as shown above in Table 1. However, the decrease in the proportion of firms investing in R&D and in EID+TT+CS, together with the stable pattern shown by K+H+S and Training, the most frequently chosen innovation inputs, may be partially linked to the strategy of switching from product to process innovation deployed by most firms in order to face the economic crisis.

The distribution of firms investing in each input according to economic sector shows that those belonging to the food industry were the leading investors in all inputs in 2000. However, in 2003, firms in the chemical products sector catch up and even surpass them in R&D investment, and by 2006 they also lead investment in training programs, a behavior linked to the introduction of novel procedures by firms in the chemical products sector (Table 6).

Interesting differences arise when analyzing the composition of inputs according to the innovation output obtained by firms—products and processes only—classifying them according to destination of sales, ownership, size, and economic sector (Table 7).

First, a high percentage of product-innovative firms innovate in all inputs, as opposed to the overall pattern, the figure being slightly lower for EID+TT+CS. It is noteworthy that R&D

[26] The category includes many non-similar subsectors. The specific industries performing innovation activities are Vehicles; Spare parts & motors; and Precision instruments.

investment is done by a significantly larger proportion of product-innovative firms relative to the average (see figures in Table 1 for a comparison). On the contrary, if innovation efforts occur only in innovative processes, investment in physical capital is still high and training is an input in which many firms invest although in a significantly lower proportion with respect to product-innovative firms, while efforts concentrated on the two most knowledge-driven inputs are significantly smaller. The decline in R&D investments seen for the totality of firms is reproduced here only by firms innovating in processes, while product-innovative firms employ an anti-cyclical strategy regarding EID+TT+CS that is lost when looking at all innovative firms.

Table 6. Distribution of Firms by Innovative Input According to Economic Sector 1998-2006
(percentage of firms)

Activity	Sector	2000	2003	2006
R&D	Food	32	25	21
	Textiles	15	14	14
	Printing & Editing	6	4	2
	Chemical Prods.	22	27	33
	Machinery & Equip.	13	14	15
	Rest of Industry	11	15	15
K+H+S	Food	28	30	26
	Textiles	15	17	15
	Printing & Editing	10	7	11
	Chemical Prods.	15	17	18
	Machinery & Equip.	14	11	12
	Rest of Industry	18	18	19
Training	Food	31	25	22
	Textiles	10	14	14
	Printing & Editing	11	9	11
	Chemical Prods.	19	20	25
	Machinery & Equip.	13	12	12
	Rest of Industry	15	19	17
EID+TT+CS	Food	33	27	22
	Textiles	12	15	18
	Printing & Editing	5	4	8
	Chemical Prods.	15	20	20
	Machinery & Equip.	13	12	12
	Rest of Industry	22	22	20

Note: R&D includes both internal and/or external; K+H+S refer to Physical Capital and/or Hardware and/or Software; EID+TT+CS gathers Engineering & Industrial Design and/or Technology Transfers & Consultancy Services; TP includes both management oriented and employees training programs.
Source: Authors' calculations based on Innovation Surveys 1998-00; 2001-03, 2004-06; ANII/DiCyT /INE.

Table 7. Innovation Input Mix by Type of Innovation Output and Firm Characteristics

(% of firms investing in each type of input)

	Products				Only Processes			
	R&D	**K+H+S**	**Training**	**EID +TT+CS**	**R&D**	**K+H+S**	**Training**	**EID +TT+CS**
All Firms								
2000	71	95	80	56	32	83	58	36
2003	69	82	76	61	22	82	58	35
2006	69	90	75	45	14	78	67	31
Exporting Firms								
2000	75	92	81	60	34	81	54	38
2003	74	90	82	63	27	87	65	40
2006	78	92	79	51	16	75	75	36
Non-Exporting Firms								
2000	52	100	80	51	31	86	63	33
2003	57	69	57	57	15	76	49	29
2006	51	86	68	32	12	82	59	24
Domestic Ownership								
2000	68	92	78	57	29	82	55	33
2003	66	83	75	61	21	83	55	32
2006	66	90	79	43	13	77	66	29
Non-Domestic Ownership								
2000	46	65	50	27	44	67	67	50
2003	44	56	52	41	25	60	45	35
2006	77	90	67	50	5	57	43	14
Large Firms - 50 or more workers								
2000	78	94	87	60	35	85	63	40
2003	77	88	82	62	28	86	68	42
2006	69	92	79	44	15	79	69	31
Small Firms - 49 or fewer workers								
2000	61	86	75	51	28	79	49	28
2003	56	73	67	59	15	78	48	28
2006	69	86	69	46	14	75	64	31
Food								
2000	77	91	89	62	47	75	61	47
2003	72	89	75	64	20	91	49	34
2006	67	86	71	48	13	90	53	27
Textiles								
2000	75	89	68	50	25	88	31	31
2003	54	88	79	71	27	87	40	13
2006	76	100	82	53	0	69	62	31
Chemical Products								
2000	94	84	94	48	47	84	68	47
2003	89	83	77	66	30	60	90	40
2006	89	89	85	41	36	64	93	36
Machinery and Equipment								
2000	64	88	76	76	100	91	55	27
2003	67	75	75	71	100	71	43	29
2006	79	79	57	43	31	69	69	19
Rest of the Industry								
2000	47	88	69	41	17	86	63	23
2003	40	73	70	38	21	72	69	48
2006	39	87	68	39	10	77	68	39

Note: R&D includes both internal and/or external; K+H+S refer to Physical Capital and/or Hardware and/or Software; EID+TT+CS gathers Engineering & Industrial Design and/or Technology Transfers & Consultancy Services; TP includes both management oriented and employees training programs.
Source: Authors' calculations based on data from Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE.

Second, if classifying firms into exporting and fully domestic- market-oriented firms, there are no significant differences in behavior regarding the preferred input mix among both groups when firms obtain only innovative processes, except for the fact that exporting firms do not adjust to the business cycle and non-exporting units do, a behavior also shared by firms obtaining innovative products as well. It seems that among firms innovating in products, exporters act procyclically on R&D and K+H+S inputs and countercyclically on training and EID+TT+CS. On the contrary, non-exporting firms are countercyclical on knowledge-intensive inputs, i.e. R&D and EID+TT+CS, and procyclical on K+H+S and training. Still, the most salient difference between firms selling in the international market as opposed to those selling in the local market is that investment in knowledge-intensive inputs is more frequent among exporters. It can thus be stated that whenever firms operate in more competitive markets, they use a mix of innovation inputs that give greater weight to research and industrial or engineering design than when restricted to the local market, where they are less affected by the domestic economic cycle, so that they need not adjust their costs as much as the rest.

Until 2006, the share of locally owned product-innovative firms that invest in all inputs was greater than that among foreign-owned companies, as is also generally the case if focusing on innovative K+H+S and on training regardless of the type of innovation output obtained. In 2006, the picture changed slightly, as more non-domestic product-innovative firms started investing in all inputs, catching up with the percentages observed among domestic companies and even surpassing them in the case of R&D and EID+TT+CS. Conversely, investment in these two inputs became more frequent among innovative domestic firms focused only on processes. The trends observed are undoubtedly linked to the behavior noted above, of the largest firms starting to innovate only in processes, together with the changes observed in overall composition by size towards a higher share of large relative to small units. In fact, a substantially higher proportion of large relative to small product-innovative firms use a mix of inputs that combines with no significant differences R&D, training and K+H+S. If only innovating in processes, the weight of training increases, while that of R&D decreases, a result that is quite expected. Furthermore, while both small and large firms display the same behavior with respect to the business cycle when innovating in products, those innovating only in processes differ in their investments in training, with large firms showing an increasing trend.

Regarding the comparative behavior among economic sectors, the proportion of firms investing in training programs is always higher when being product innovative than when innovating just in processes, with the apparent exception of firms in the chemical products industry after the downturn in 2002. This activity, mainly driven by the behavior of units in the pharmaceutical sector, is highly intensive in R&D, as are firms innovating in processes in the machinery and equipment sector. Regarding innovative capital, the frequency of firms investing in that input is always high, but those in the food sector have the largest figures throughout the period, both when innovating in products and when doing so only in processes. Thus, no major distinctive patterns can be linked exclusively to the sector in which innovative firms operate.

A final dimension of innovation behavior refers to the subjective view of managers with respect to the role of agents associated with the activity, such as public institutions, NIS actors or other economic agents linked to the firm in diverse ways (competitors, suppliers, related enterprises, etc.). This role is evaluated from various perspectives, including financing, the availability of information, and the existence of training programs. Similarly, the mechanisms giving rise to innovation activities are linked to the perception of managers of the obstacles faced, the goals they pursue by innovating and the eventual impacts observed by those undertaking innovation. These dimensions may be heterogeneous depending on specific characteristics of firms.

According to Table 8, firms invest in innovation inputs mainly to reduce costs. Large firms also pursue innovation activities in order to increase their products' quality and to maintain or increase their market share. Environmental concerns and related issues are not a goal for at least 60 percent of innovative firms, regardless of their size. The motivation behind innovation activities as stated by firms is consistent with the impact they claim to obtain from innovative practices, which are mainly related to lowering labor costs by means of increasing the firm's productive capacity and maintaining and/or increasing their market share. Small firms claim increased production flexibility and better use of human capital resources as further impacts, which is consistent with the declared aim of reducing costs and, for large units, gains in quality. Firms are mainly looking for technological assistance and information when related to NIS agents, no matter what their size or their innovative character. This behavior is increasing over time for small firms. Large enterprises have also evolved towards associating with NIS agents looking for support in their training programs. Surprisingly, financing is not among the most important objectives sought through these links, either for large or small firms.

Table 8. Obstacles, Goals and Links with NIS Agents by Size, 1998-2006

	Large firms[1/]	Small firms
Objectives	Reduce costs Keep/increase market share Improve products' quality	Reduce costs
Impacts	Increase market share Increase productive capacity Improve products' quality	Better use of the staff's capacities Increase productive capacity Increase flexibility in production
Links	Technology Assistance Training Information	
Sources	Internal sources Clients Specific knowledge-generating agents (consulting firms, journals, conferences, fairs)	
Financing	Financial System Other firms	
Agreements	Commercialization agreements Training agreements	
Obstacles	Small market Return horizon for investments	Small market Market structure Access to financing and information

[1/] Large firms: 50 employees and more; Small firms: 49 or fewer employees.
Source: Authors' calculations based on data from Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE.

There has been a change in firms' behavior with respect to which type of agents to approach when looking for financing. While in 2000 "related firms" was stated as the first choice, by 2006 financial institutions became the preferred option. The behavior is shared by innovative and non-innovative firms, although 70 percent of firms in the former group have applied for financing, while only 35 percent of non-innovative firms have done so. Small firms declare lack of financing as one obstacle to innovation, although they do not relate to NIS agents pursuing that goal. This could reflect the inability of small firms to fully access or make use of the tools provided by the NIS in terms of specific help, beyond information and technical assistance.

An additional limitation is the perception, also shared by large non-innovative firms, that the time horizon in which returns from innovation are obtained is too wide, which suggests these firms are more risk averse than the rest, at least in terms of innovation activities.[27]

[27] Although for different reasons, small firms may be more risk averse than large firms to face misinvestments and their financially associated problems, e.g. lack of liquidity and lack of sustainability of the innovation effort in the

Small non-innovative firms also consider the lack of information, both technical and on market characteristics, as a major obstacle. This may further signal the need for a better design of information channels to reach small firms. Finally, the size of the market, as well as its structure in the case of small units, is seen as a further disadvantage for firms to engage in innovative practices.

Although data on cooperation agreements are available only for 2006, these agreements relate to commercialization practices and training programs, among both innovative and non-innovative firms, but only those in the first group have agreements for developing new technologies.

When analyzing the sources of information used by innovative enterprises, the most important one declared by firms is internal sources, followed by the firm's clients. However, there is a time trend towards establishing links with both general and specific knowledge-generating agents, such as the university, consultants, and other sources, such as specialized journals, fairs, and conferences. This fact underscores a trend over time towards the professionalization of innovation activity, and it may also suggest that firms have started to look at innovation as a means of economic development. It also reveals an improvement in the way innovation-related information is publicized and communicated by public and private institutions.

Furthermore, neither the lack of talent nor the failure or poor development of public policies and technical institutions related to innovation are among the main obstacles declared by firms, in line with the conclusions in Hausmann et al. (2005).

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long run. On the other hand, large firms may be more able than small units to sustain an innovation effort for longer until it bears results due to reputation issues; to accountability vis-à-vis stockholders or to the fact that those funds could have been invested in something else, yielding short-term results that would have an immediate positive impact on the firm and its managers' image.

4. Measures of Innovation Output and Inputs

4.1 Innovation Output Indicators

Variables accounting for innovation output can be defined in several ways, the most popular measures being the number of patents applied for and/or already obtained during the period covered by the survey, as well as its accumulated number; sales of innovative products as a percentage of total sales or total non-financial revenue; and binary variables stating whether or not the firm obtained an innovative output by output category. Instead of using these variables, we propose an indicator *proxying* the value of the innovation output through its relevance, as will be explained in detail in the next subsection. The comparative performance of our indicator and the variables above can be found in Cassoni and Ramada (2009b). In what follows we discuss the abovementioned indicators for innovation output and propose other indicators to overcome their limitations.

4.1.1 Number of Patents

A widely used index of innovation output is the number of patents.[28] However, small firms in non-central countries, despite performing innovation strategies and obtaining innovative results, are a lot less likely to apply for international patents than large enterprises or firms in developed countries. This is the case of several Latin American countries for which there is evidence that the use of patent applications as an indicator of innovation output leads to ambiguous results (Arocena and Sutz, 2008). The main factors underlying this finding are the high associated costs, especially when applying for an international patent, and the generally insufficient information available on the matter. The number of patents requested and obtained by Uruguayan manufacturing firms is negligible—265 and 242, respectively—considering 494 firms over a 10-years period. That is, on average, only 26 patents were requested and 24 were obtained each year if considering all 494 manufacturing firms analyzed over the 10-year period (this is equivalent to one patent requested/obtained annually by every 100 firms). If focusing on international patents, these annual figures fall to 8 and 7, respectively, that is, one patent per 300 firms. The stylized fact further supports the hypothesis that the core of innovation activities in Uruguay, and probably in any non-developed country, refers to processes and not to innovative products (Hall

[28] See, e.g., Crépon et al. (1998).

and Maffioli, 2008; Bianchi et al., 2008; Arocena and Sutz, 2008). Consequently, we are not using this indicator of innovation output in our analysis.

4.1.2 The Share of Innovative Sales in Total Sales

A similar critique is in place for the indicator based on the share of innovative sales in total sales or revenue. Generally defined in surveys as the sales value of innovative products, the indicator is zero not only for non-innovative firms but also for those that innovate only in processes, thus becoming useless for analyzing process-innovative firms.[29] Its use has been justified in the literature by noting that the share of innovative products in total products times the marginal product of knowledge capital is almost equal to the rate of growth of knowledge capital times the product elasticity with respect to this additional production factor. However, the equivalence holds only under certain conditions related to innovative and standard products having equal rates of profits and to firms' knowledge-capital endowment in the previous period being large enough relative to the size of investment. Further, if used in a productivity equation derived ignoring intermediate consumption, the indices have to be defined in terms of value-added and not sales.[30]

4.1.3 Binary Indicators for Innovation Output

Another strategy found in the literature on proxy innovation output is substituting the knowledge-capital equation by redefining it as a function that relates the specified triggering factors of innovation, including the size of the effort, to a binary variable stating if the firm generated or not an innovative output. As such, the index is uninformative with respect both to the value of the obtained output and to the returns of innovation with respect to firm performance. However, it may serve to analyze if there are differences between the diverse types of innovation output regarding their determinants and their impact on the chosen indicator of firm performance. Furthermore, it is possible to combine the use of a dummy variable accounting for innovative processes with the share-of-sales proxy for innovative products, as Van Leuween and Klomp (2006) have shown. As the strategy is a step forward, the impact of innovative processes is still restrained to scale effects. The analysis may be improved by creating binary variables that interact with the share of innovative sales whenever innovative processes exist, so as to allow the

[29] The literature including new processes as one innovation output does not generally discuss the issue, Van Leeuwen and Klomp (2006) being one notable exception.
[30] The indicators introducing those corrections are described in Cassoni and Ramada-Sarasola (2009b).

elasticity to vary with a diversified output. In doing so, some insight on the eventual existence of complementarities between diverse types of innovative output may be also obtained.[31]

4.1.4 An Alternative Indicator for Innovation Output

When modeling the odds of obtaining an innovation output by means of binary variables, any innovation output is assigned the same degree of relevance and all types of outputs are given the same weight. In order to surmount this shortcoming, we define a new indicator for innovation output adding up the diverse output classes—the four categories available in the surveys—but weighting each of them by their own degree of novelty. Relevance is defined in terms of the output being innovative only at the firm level—the lowest degree; innovative at the local market level; or at best, innovative with respect to the international market, as declared by the firm.

One possible way to arrive at the weighting scheme described above would be to assign increasing values for each relevance category, ranging from 1 to 3, so that the output indicator may vary between 1—when innovation refers to just one type of output and it is innovative only at the firm level—to 12 where there is international market-level innovation in the four categories of output reported. However, this method implies that the relative increase in the innovation's relevance is the same among the three categories. To avoid this limitation, given the small size of the Uruguayan market, we further sophisticate the formula by generating incremental differentials between weights. In non-developed economies, it is much more difficult to obtain an innovation output that is innovative at the international market level than one that is novel with respect to the local market or the company. Under this assumption, the weights are defined as the inverse of the share of firms that obtain an output of each specific degree of relevance among the total number of firms obtaining that output.[32] As such, the output indicator's lower bound is 1—in case all firms in the category innovate only at the firm level in just one type of output. It is theoretically unbounded, as its highest value would correspond to the case in which there is only one firm that innovates at the international market level in all four types of outputs, with the number of firms innovating in each type of output being infinitely large.[33] In Table 9, we report the weighting scheme for 2006.

[31] See Milgrom and Roberts (1995) for a mathematical approach to complementarities and a brief survey on the applied literature.
[32] For a description of the weighting schemes and output indicators, as well as for a comparison in terms of their performance using Uruguayan data, please refer to Cassoni and Ramada-Sarasola (2009b).
[33] In our 2006 sample the actual maximum reached is 36.

Table 9. Innovation Output and Relevance, Weights 2006

Products		Organizational Process	
Firm	3.00	Firm	1.33
Local Market	2.43	Local Market	5.12
International Market	3.92	International Market	18.22
Productive Process		**Commercialization Process**	
Firm	1.91	Firm	2.07
Local Market	2.96	Local Market	2.70
International Market	7.20	International Market	6.75

Source: Authors' calculations based on data from Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE

4.2 Innovation Input Indicators

The indicators used to measure innovation inputs that are most frequently found in the literature are the amount of expenditure devoted to R&D and its share in total sales or total non-financial revenue, the number of employees,[34] the existence of formal R&D units, and the number of employees or the proportion of the firm's workforce engaged in R&D activities. Recently, the amount of expenditure devoted to other innovation inputs and its share in total sales or revenue have also been used, as is the case of physical capital, hardware and software, and training programs. However, the use of total expenditure or of a sole input may not be optimal to analyze the input-output ratio, as both ignore the eventual existence of complementarities. Further, differences in nature among the diverse innovation inputs will most likely result in differing amounts and types of innovation output that will not be accounted for by using total expenditure. Nor does it allow for analysis if concentrating expenditure in a particular input mix leads to differentiated types of output or if it impacts the degree of novelty attained. As a first approach to improving the measurement of the intensity of innovation, we build an overall input indicator

[34] The choice between these indicators depends on the aim being to measure the financial effort done for innovating or the research capital to labor relative intensity. We performed the exercise of estimating the models using both variables. The results differ among both specifications in terms of the impact of the scale of production (negative if measuring effort per employee while inexistent if using the financial effort measure) and that of the capital-labor ratio effect (positive vis-à-vis nil, respectively), since small firms are generally more labor-intense than large units. The role of belonging or not to an economic group has also the opposite sign, a result that is also related to the type of technology prevailing in firms of different sizes and the existence of spillovers. An analogous explanation may underlie the positive effect of public financing when firms are less capital intense that is absent when defining effort in terms of revenue. No differences are carried over to the input-output equation or to the productivity model. Results are available upon request.

taking into account the degree of diversification of the firm's innovative effort. The indicator is built as a normalized Herfindahl index using as the weighting factor the amount spent in each type of input as a proportion of total expenditure in innovation inputs.

The Innovation Input Concentration Indicator (IICI) proposed above should be built based on the nine classes of innovation inputs as reported in the IS. Given that we use an aggregation of inputs into four categories, as explained in Section 3.2, we build the IICI2 based on those four categories. As can be seen in Table 10, the results support our aggregation scheme given the similarity between the mean values of IICI and IICI2.[35] The intuition behind using this indicator is to assert that a more concentrated effort with investment focused on few innovation inputs—say, only in R&D—yields different results than a more diversified innovation effort, investing across several areas—e.g., R&D, capital, and training.[36] One could therefore hypothesize that a more diversified innovation effort across types of inputs should decrease the risk of not obtaining significant innovation results, in the same fashion that diversification works for a financial portfolio. In fact, the risks associated with R&D innovation should decrease with diversification across inputs.

Table 10. Innovation Input Concentration Indicator
Descriptive Statistics

	Obs.	Mean	Std. Dev.	Min.	Max.
IICI	2,314	0.303	0.377	0	1
IICI2	2,314	0.326	0.401	0	1

Source: Authors' calculations based on data from Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE.

5. Econometric Results

In this section we estimate a model framed in equations (CDM_1) to (CDM_4) depicted in Section 2.2 using data from the IS only for 2006. We measure innovation effort in financial terms and use

[35] For a thorough description of the IICIs and a comparison of their relative performance, see Cassoni and Ramada-Sarasola (2009b).

[36] For example, R&D effects on the odds of attaining an innovation output are considered to be highly uncertain, with uncertainty very much linked to the sector in which R&D is pursued, while its effects occur with time lags that vary given firm and sector characteristics. In addition, its overall impact may also suffer from the interaction or be dominated by investments in other production factors. In Mairesse and Sassenou (1991), the authors suggest looking at different innovation inputs or types of R&D, since their returns and time-horizon-associated risks differ and may therefore affect the generation of innovation output differently.

our own innovation output indicator. We have proxied the theoretical variables included in the models using data from the IS except when stated, as follows:[37]

- Propensity to innovate: g_i: binary variable equal to 1 if the firm invested in any innovation input in the 2004 to 2006 period
- Innovation effort:- k_i: log of total expenditure in innovation inputs over value of sales in 2006 (IS and EAS)
- Innovation output: t_i: log of the innovation output indicator as defined in Section 4.1
- Productivity: q_i: log value added in 2006 pesos over total employment (EAS)
- Independent variables - $\boldsymbol{Z}_i$, $\boldsymbol{X}_{0i}$, $\boldsymbol{X}_{1i}$, $\boldsymbol{X}_{2i}$, $\boldsymbol{X}_{3i}$ refer to firm level characteristics and characteristics of the firm's innovation activities. The variables are described in detail in Table A.2. Many of them are defined as binary variables stating if a characteristic is or not observed (equals 1 if yes). We also include sectoral dummy variables for 12 economic sectors at the ISIC 2-digit level.
  - $\boldsymbol{Z}_i$: Capital/Labor - Rate of growth Labor Rate of growth
  - $\boldsymbol{X}_{0i:}$ Size: 20-49 workers; Size: 50-149 workers; Size: 150 workers & more; Foreign ownership; Full Foreign ownership; Economic group; Exports over sales (%); Avg. labor productiv.- 1 lag (log); Capital/Labor - 1 lag (log); Engineers/ Professionals-firm (%); Productive capacity - % use; Formal R&D unit - 1 lag; Obstacles: firm; Obstacles: market; Obstacles: macro; Information High Relevance
  - $\boldsymbol{X}_{1i}$: R&D; K+H+S; Training Programs; EID+CS+TT; Size: 20-49 workers; Size: 50-149 workers; Size:150 workers & more; Foreign ownership; Full Foreign ownership; Economic group; Export; Full export; Avg. labor productiv. - 1 lag (log); Capital/Labor - 1 lag (log); Engineers/Professionals firm (%); Formal R&D unit - 1 lag; IICI2; Financing: External resources; Financing: Related agents (%); Financing: Public sector (%); Financing: Banks (%); Financing: International (%);

[37] Descriptive statistics for most variables, if not previously reported, are included in Tables A.1 and A.2 of Appendix A.

- X_{2i}: IICI2; Size: 20-49 workers; Size: 50-149 workers; Size: 150 workers & more; Engineers/Professionals firm (%); Formal R&D unit - 1 lag; Share of foreign capital (%); Full Foreign ownership; Full exporter; Exports over sales (%); Capital/Labor - 1 lag (log); Link with NIS agents; Link: Technical assistance; Link: R&D; Link: Training; Link: Information
- X_{3i}: Innovation in Products; Only Inn. Processes; Only Inn. Non-product. Process; Inn. in Productive Process; Inn. in Commercialization Process; Inn. in Organization Process; Capital/Labor - Rate of Growth; Labor - Rate of Growth; Size:20-49 workers; Size: 50-149 workers; Size: 150 workers & more; Avg. labor productiv.- 1 lag (log); Productive capacity - % use

Regarding the statistical models specified, a first issue to be taken into account is the potential existence of selectivity bias of diverse origins. One of the most frequent causes of bias encountered in the literature stems from having information only for innovative firms, as is the case of European surveys. We can ignore these biases due to the fact that the Uruguayan surveys do not share this characteristic, as non-innovative firms are also included in the sample. Nonetheless, it might be argued that self-selection may be present or else that there is a censoring of firms in terms of reporting 0 expenditure although some investment was actually done (e.g., when the amount of resources invested is lower than a certain threshold). We thus estimate the model using the procedure proposed by Heckman (1979). The results, however, support the independence of the models. In addition, selectivity bias linked to the design of the samples themselves might exist.

The Uruguayan sample is chosen every year since 2001 according to a stratified sampling model that includes all large firms (employing above 49 workers or reporting revenues above a certain threshold) plus units selected by random sampling within independent additional size strata. Further, even within the small strata two economic sectors—food and chemical products—have a higher weight in the sample. As such, our sample design implies that there are firms that must be described as certainty sample units. Hence, we further account for the biases introduced by the Uruguayan sample design by estimating a weighted regression, as suggested in the recent literature on microeconometric analyses dealing with these issues (Fazio, Lam, and Ritchie, 2008, and references therein).

The sample design correction has a significant impact on the many estimated coefficients in the Uruguayan case, as shown in Tables B.1 and B.2 of Appendix B, so that the conclusions stemming from the estimated models would be misleading with respect to diverse dimensions of the innovative behavior of firms if the sample design is not accounted for. More critical still is the fact that these perverse effects have a key impact on the estimated scale effects and returns on innovation output. We find that ignoring sample design corrections changes the significance of variables accounting for size, origin of firms' capital, exporting behavior, capital-labor intensity, productive capacity, and labor productivity. The results are in line with the findings of Fazio, Lam, and Ritchie (2008) regarding the fact that the biases are larger for coefficients corresponding to variables used in the sample design (as is the case of size) and are highly correlated with these variables (as is the case of full exporting firms, full foreign ownership companies, or firms belonging to an economic group). The biases do not disappear unless a multiplicative scheme is used. Other strongly biased coefficients are those linked to variables that suffer from measurement error that is significantly larger for firms in the different strata defined by the sampling model used (as is the case of physical capital for small firms).

Regarding innovation output effects, the impact of ignoring sample design is that no difference is found in the returns on innovation when the output is restricted to processes or relative to the case in which it also involves products, while differentiated scale effects also disappear. The result is explained by the fact that small firms in the food and chemical products sectors, mostly product innovative firms, are of mandatory inclusion, so that the weight of the random strata is just 5 percent in this case. Further, these innovative firms obtain an innovation output of an almost identical average relevance as that among certainty units (1.83 and 1.83, respectively), thus rendering irrelevant the misuse of the same sample weight. On the contrary, randomly selected firms are 12 percent of those innovating only in processes, the relevance of the output obtained being substantially lower than that of mandatory inclusion units (0.68 *versus* 1.05). Consequently, the overrepresented weight given to small random units prevents capturing the actual impact of innovation processes on productivity.

5.1 The Propensity to Innovate

Factors influencing the propensity to innovate that are considered in our model relate, first, to technological characteristics of the firm as embedded in the quality of its production factors as well as in their absolute and relative use (including the skill level of its workforce as expressed by the percentage of engineers in the total number of employed professionals, the previous existence of a formal R&D unit, the pre-existing capital intensity of the firm's technology, the past average labor productivity, and the percentage of installed capacity used). Second, we include structural characteristics that may ease the firm's access to both information and financial resources, as measured by the scale of the firm, its membership in an economic group or network, the exporting character/intensity of the firm, and whether the firm is domestic or foreign-owned. We also control for the firm considering certain type of information eventually obtained by firms from NIS agents as highly relevant for their deciding on pursuing innovation activities. In order to evaluate the eventual differentiated impact of obstacles to innovate depending on whether they stem from the firm, the market, or the macroeconomic framework, we include three binary variables stating which of these facets was considered by the firm to be the most relevant. Binary variables for economic sectors are also included.

According to our results, Uruguayan firms are more prone to innovate the larger their size, the higher the engineers-to-professionals ratio among their employees, the higher their past labor productivity level, the higher their past physical capital to labor intensity, and the higher their percentage of installed capacity used. A further triggering factor is the firm's ability to obtain relevant information from NIS agents. In contrast, the propensity of firms to innovate decreases for firms that are part of a larger economic group, for exporting firms, and for those declaring that obstacles at the market level restrain them from pursuing innovation activities. The origin of the firm's capital does not affect the unit's propensity to innovate.

Regarding the effect of the scale of production—as measured by the firm's size—the evidence shows that larger firms have a greater propensity to innovate (see marginal effects reported in Table 11). The fact that the capital intensity of the firm's technology relative to labor and the firm's previous labor productivity level are positively related to the propensity to innovate indicates that innovation behavior is not triggered by lack of productivity or insufficient capital to labor intensity. On the contrary, those firms that already display high levels of capital to labor intensity and productivity see innovation activities as a further tool to improve their productivity. Indeed, firms with a highly productive workforce are probably better prepared to leverage and capitalize innovation efforts. This is also consistent with the positive correlation between the proportion of engineers and innovation propensity. As expected, a further factor triggering innovative behavior is a high level of usage of installed capacity, given that innovation activities may be understood as activities allowing for the expansion of the firm's productive capacity.

Table 11. Innovation Propensity and Innovation Intensity

	Innovation Propensity	Innovation Intensity
Variables	**All firms (dy/dx)**	**Innovative firms**
R&D – Dummy	------------	0.8384***
K+H+S – Dummy	------------	2.4659***
Training Programs - Dummy	------------	0.2760
EID+CS+TT – Dummy	------------	0.4416*
Size: 20-49 workers – Dummy	0.1101	0.7110
Size: 50-149 workers – Dummy	0.2125**	-0.6137
Size: 150 workers & more – Dummy	0.4024***	-0.2417
Foreign ownership - Dummy	0.2150	-1.5979***
Full foreign ownership – Dummy	-0.1158	1.3401***
Economic group – Dummy	-0.1844***	0.5517
Export – Dummy	------------	-0.2325
Full export – Dummy	------------	0.9268
Exports over sales (%)	-0.1092*	------------
Avg.labor productiv.- 1 lag (log)	0.1347***	-0.3412
Capital/Labor - 1 lag (log)	0.0663***	0.0826
Engineers/Professionals firm (%)	0.2078**	0.2793
Productive capacity - % use	0.2255*	------------
Formal R&D unit - 1 lag – Dummy	-0.0067	0.5526*
IIC12	------------	1.7072***
Obstacles: firm – Dummy	0.0658	------------
Obstacles: market – Dummy	-0.2633***	------------
Obstacles: macro – Dummy	0.0385	------------
Information High Relevance - Dummy	0.1300**	------------
Financing: External resources - Dummy	------------	0.3955
Financing: Related agents (%)	------------	-0.3337
Financing: Public sector (%)	------------	1.8258
Financing: Banks (%)	------------	0.0690
Financing: International (%)	------------	-1.6920**
PSUs/Strata [1/]	457/93	457/93
Censored Observ.	------------	225
F(k,N-k) [2/]	15.71***	23.40***
Rho [3/]	-0.4233	

Notes: All observations are included in the Innovation Propensity equation, specified as a Probit model and estimated by FIML. Observations in the Innovation Intensity equation are the resulting self-selected innovative units. The equation was specified as a Tobit model corrected by selectivity bias and estimated by FIML. Both models used observations weighted by sample design factors. Dummy variables are 1 if the definition of the variable is registered (eg, Export-dummy =1 if exporter). Rates of growth are defined as the difference of logs. Unless stated, variables are ordinal. Dummy variables for economic sectors are included in all equations. */**/*** mean coefficients are statistically significant at 90, 95, and 99 percent confidence levels, respectively.

[1/] "PSUs" are the primary sampling units; "Strata" are those defined in the sampling model used in the surveys.

[2/] F-statistic for the overall significance of the model.

[3/] "Rho" refers to the estimated correlation coefficient between the main equation and the selection function.

The fact that units that are part of a larger—probably international—economic group makes them less prone to innovate suggests that these type of firms in Uruguay are not part of R&D and innovation behavior decisions, defined by other units within the group, probably outside the country. It may also be the case that these companies are subject to spillovers from other firms in the network, rendering it unnecessary for them to engage in innovation.

Finally, the larger a firm's share of exports in total sales, the less prone it is to innovate. This suggests that Uruguayan firms that have a more diversified selling market have fewer incentives to innovate, thus revealing the difficulties they face in attaining international level innovation. Thus, the expected returns of the activity are, at least in the short term, insufficient.

No sectoral differences in the propensity to innovate were found with the exception of two industries—oil and derivatives and tobacco—that display greater odds than the rest. As these are oligopolistic activities, the result points to greater benefits of innovation the more concentrated the market, as was theoretically expected.

5.2 The Intensity of the Innovation Effort

Once the decision to innovate has been undertaken, the resources to be devoted to it are decided according to the firm's technology. This determines the feasibility of the type of innovation output to be pursued and hence the required inputs, depending on the economic framework and the prevailing market conditions. Since the intensity or size of the effort is measured in terms of sales value, it reflects the financial pressure that the firm is able to bear given the above factors, but also subject to the origin of the financial resources needed and whether they are partially or totally external to the firm. In order to capture the eventual differentiated effect that choosing one input or other may have on the effort made, we also include binary variables stating whether or not the firm invested in each type of input. The degree of diversification/concentration of expenditure among the different types of innovative inputs (the IICI2 indicator) is added as a further control of the chosen mixture. Binary variables for economic sectors are also included.

The most noteworthy result refers to the role played by the innovation input mix used. Once controlled for the costs of inputs—expected to be highest for physical capital acquisitions and lowest for training programs—a diversified investment lowers the size of the effort needed while spending on R&D is an incentive to invest as if the expected returns in that case were larger than when R&D is ignored. In other words, firms concentrating their innovation effort on a few innovation inputs are spending more than those diversifying their innovation efforts. This is in line with the finding that firms displaying this behavior are primarily investing in physical capital. The comparison of the coefficients for the dummies capturing investments in R&D, K+H+S and EID+TT+CS are further elements pointing in this direction.

Moreover, once the decision of pursuing innovation activities has been taken, neither firm size membership in a larger economic group, being an exporter, previous capital to labor intensity, the firm's talent composition nor past productivity affect the extent of the firm's innovation effort. That is, the financial effort devoted to innovation activities does not depend on the production factor intensity, their relative quality, or the scale of production (Table 11). This result underscores the fact that once firms have decided to innovate, the size of the innovation effort becomes a fully financial decision that relates to the existence of a formal R&D unit, concentration of the innovation expenditure, and the type of innovation inputs chosen for the investment. The only firm attribute that still plays a role in the determination of the innovation effort is the foreign share in total capital. Since the effect is negative, it disappears whenever the firm is fully foreign.

The most likely cause of this result is linked to the relatively greater expected complexity of the decision-making process in mixed-capital firms. The results for the variables referring to financial sources for the innovation effort displayed show no differences between exclusively internal and external sources, unless the external source are international institutions. In this case, the effort would be smaller the larger the share of international resources in total financing. Plausible explanations could be associated with the inability of Uruguayan firms to generate strong enough links with these agents or to convince them of the reliability of their enterprise. Individual effects by economic activity suggest that there exist sectoral specificities that, other characteristics being equal, generate differentiated sizes of the effort devoted to innovation practices by industry.

5.3 Input-Output Equations

The input-output equation estimated here reflects the impact of the effort devoted to investing in innovation inputs on the extent and relevance of the innovation output obtained by those firms, if any, taking into account firm-specific attributes. We also control for the role that NIS agents may have on the relevance of the innovation, both regarding the type of link established and the providing agent, as the effects found would capture likely bottlenecks in the innovative behavior of firms as well as the relative efficiency of the diverse NIS agents. Binary variables for economic sectors are also included. All other things being equal, the size of the effort devoted to innovation activities has a positive effect on the relevance of the innovation output obtained. The size of the effort should be augmented by 11 percent in order to increase the relevance of the innovation output obtained by 1 percent, *ceteris paribus* (Table 12).

Having a formal R&D unit inside the firm or associating with NIS agents, especially if seeking R&D assistance, would further enhance the degree of relevance of the innovation output. The evidence supports the above-hypothesized critical role played by R&D investment—the innovative input *par excellence*—and the lower effort required whenever expenditure is diversified among innovative inputs. Firms that are more capital-intensive tend to attain a higher-relevance innovation output than labor-intensive units, as do large and medium companies relative to small units. Unexpectedly, micro firms (with fewer than 19 workers) would obtain a more relevant innovation output in 2006, other things being equal, than small establishments (20 to 49 workers). A likely reason is that in order to survive the 2002 outstanding financial crisis, micro firms were forced to adapt by introducing novel products and/or procedures.[38] At the same time, large innovative enterprises probably got a lower return on their innovation output than their historical average, due to their switching from product to only process innovation output. Individual effects by industry are significant, so that not only is the effort displayed by firms different according to economic sector, but also the degree of relevance of the output obtained is not homogeneous.

A final result shows that exporting firms achieve a higher degree of relevance in the innovation output obtained, an expected result since they operate only in the international market. Firms that are fully owned by foreign entrepreneurs behave similarly, since they are highly export-intensive, product-innovative companies.

5.4 Productivity Growth

The impact of the innovative behavior of firms on the rate of growth of labor productivity is captured by specifying a Cobb-Douglas production technology, in which the accumulated innovation output enters exponentially as a third factor of production. Hence, the predicted value

[38] Note that we are only analyzing the behavior of those micro firms that report information for the whole 1998-2006.

of the index of relevance of the innovation output estimated in the input-output equation is added to the log growth of productivity linearly. We split the index in two, depending on the innovation output involving products or only processes of any type. We also control for scale effects of the diverse types of innovation output reported in the surveys, further including the possibility of getting only non-technological innovative processes. The extent of productive capacity usage, the scale of production, and individual effects associated with unobservable sector characteristics are also included as determinants of productivity growth. We add the level of labor productivity in the previous period in order to allow for adjustment costs.

The resulting technology exhibits decreasing returns to scale (Table 12). However, the result may be an underestimation of the actual returns due to mismeasurement of the physical capital stock, which may explain the low resulting product elasticity (0.08), as elasticity relative to labor is quite reliable (0.64). Nonetheless, a low elasticity of physical capital would reinforce the starring role of the skill level of the workforce as key for engaging in innovation activities. As expected, increases in productivity decelerate the closer to full capacity the firm is and the smaller the scale of production, given the relative labor intensity of units of different sizes. The growth rate of productivity is not identical by industry.

The results reveal that the returns on innovation for Uruguayan firms are significantly positive and of a much larger size for process-only innovation than for product innovation. A 10 percent increase in the degree of relevance of the innovation product, evaluated at the mean value—6.15—would generate an increase in the growth rate of labor productivity of 3 percent. In the case of firms innovating only in processes, the figure rises to 5 percent (the mean value of the indicator for processes is 3.7).[39] This result further supports our initial hypothesis about the key role of accounting for process innovation, at least for a small, developing country like Uruguay. Regarding scale effects, the coefficients show that the importance of product and of productive processes is smaller relative to that of commercialization practices. Still, only a small number of firms innovate in commercialization strategies, suggesting that most Uruguayan firms pursue mediocre—non-innovative—strategies for commercializing their products. The important effect of innovating in commercialization processes thus leads to a strong recommendation towards seeking this type of innovation as a way to overcome the international positioning of Uruguay as

[39] The difference between the effect on productivity of innovation in products and process innovation is statistically significant.

a binding constraint for firm performance. On the contrary, innovating only in non-productive processes has a negative impact on productivity growth. In summary, neglecting process innovation is very likely to be one of the reasons why previous research for non-developed countries has failed to find a significant effect of innovation on firm productivity.

Table 12. Innovation Output and Productivity

	Innovation Output	Productivity Growth
Variables	Firms with Innovative Output	All firms
Total Innov. Exp./Sales (log)	0.0909***	------------
Innov. Output – Products (log)	------------	0.0486***
Innov. Output - Only Process (log)	------------	0.1328***
IICI2	-0.3807**	------------
Innovation in Products– Dummy	------------	0.1208
Only Inn. Processes– Dummy	------------	-0.1226
Only Inn. Non-product. Process– Dummy	------------	-0.5510**
Inn. in Productive Process– Dummy	------------	-0.2905*
Inn. in Commercialization Process– Dummy	------------	0.2317**
Inn. in Organization Process– Dummy	------------	-0.1974
Capital/Labor - Rate of Growth	------------	0.0771*
Labor - Rate of Growth	------------	-0.2758**
Size: 20-49 workers – Dummy	-0.6088***	0.1202
Size: 50-149 workers – Dummy	-0.3782***	0.2274**
Size: 150 workers & more – Dummy	-0.2846**	0.1865*
Engineers/Professionals firm (%)	0.0477	------------
Formal R&D unit - 1 lag – Dummy	0.4591***	------------
Share of foreign capital (%)	-0.2656	------------
Full foreign ownership – Dummy	0.3987**	------------
Full exporter – Dummy	0.6277**	------------
Exports over sales (%)	0.1133	------------
Avg.labor productiv.- 1 lag (log)	------------	-0.4424***
Capital/Labor - 1 lag (log)	0.0907***	------------
Productive capacity - % use	------------	-0.2600*
Link with NIS agents – Dummy	0.4185***	------------
Link: Technical assistance - Dummy	0.1020	------------
Link: R&D – Dummy	0.3246***	------------
Link: Training – Dummy	-0.0350	------------
Link: Information - Dummy	-0.0666	------------
PSUs/Strata[1/]	233/69	453/93
F(k,N-k) [2/]	52.73***	42.48***

Notes: Observations included in the Innovation Output equation, specified as a Tobit model and estimated by FIML, refer only to innovative firms. In the productivity growth equation all firms are included, the model being specified as a dynamic linear regression and estimated FIML. Both models used observations weighted by sample design factors. Dummy variables are 1 if the definition of the variable is registered (e.g., Export-dummy =1 if exporter). Rates of growth are defined as the difference of logs. Unless stated, variables are ordinal. Dummy variables for economic sectors are included in all equations. The first three variables in the table (in bold) refer to predicted values. */**/*** mean coefficients are statistically significant at 90, 95, and 99 percent confidence levels, respectively. [1/] "PSUs" are the primary sampling units; "strata" are those defined in the sampling model used in the surveys. [2/] F-statistic for the overall significance of the model.

5.5 Comparison to Existing Literature

One of our results points to the existing literature not finding significant effects of innovation on firm performance for less-developed countries due to its non-differentiation of product from processes when explaining the generation of innovation output. Aiming at further testing this result, we estimate the above models using some of the standard *proxy* variables, i.e., the share of innovative sales in total sales and a binary variable that reflects the probability of obtaining an innovation output. We estimated a Tobit model in the first case, with right-handed truncation since the share of sales equation is specified as log-linear and a Probit model in the second case. The impact of each type of innovation output on the rate of growth of labor productivity was estimated using the predicted values of the variables, as before. The relevant estimated coefficients are reported in Table 13.

Table 13. Comparison of Econometric Results

Input-Output Equation	**OIOI** (in logs)	**Share of Sales** (in logs)	**Probability of Innovation Output** (dy/dx)
Log(Expenditure/Sales)	0.0909***	-0.0654	0.1977***
Productivity Equation*/	**Products**		**Only Processes**
OIOI	0.0486***		0.1328***
Share of Sales (%)	-0.1259		---------
Prob. Innov. Output	0.2377		0.0447

Note: All models are estimated using an identical specification to those reported in Tables 11 and 12. Results are available upon request. OIOI is our innovation output indicator (Section 4.2). */Variables *proxying* innovation output in the productivity equation are the predicted values stemming from the Input-output model.

The use of the innovative to total sales ratio as a *proxy* variable for innovation output is unable to capture any effect of the financial effort on the innovation output, in line with the results already reported by other research for Latin America and opposed to our findings for Uruguay. However, the impact of interest is identified when modeling the odds of getting an innovation output of any type instead. Its estimated magnitude is such that a 10 percent increase of the ratio of innovative expenditure to sales raises the odds of getting an innovation output by 2 percent. Regarding the productivity equation, the predicted values of the two standard *proxies* have no impact on productivity growth, so that their results point to zero returns on innovation output on firm performance, also in line with results reported in previous literature.

The comparison of the models summarized above underscores the importance of measuring process innovation, beyond the standard practice of using binary variables. It also points to the need to conduct further studies to identify its specific role in the dynamics of innovation. Similarly, the evidence reported throughout this section strongly suggests that only by differentiating and/or qualifying innovation output, either by its relevance or by any other dimension that is significant for firm performance, will models be able to accurately capture the existence and magnitude of the returns on innovation output.

6. Conclusions

It has been suggested that scant investment, particularly if related to novel activities, is one likely cause explaining the meager performance of the Uruguayan economy in terms of its per capita growth rates in recent decades. Some recent studies have hypothesized that risk aversion, lack of financing, and inadequate public policies may explain the gap between the state of the art in the country and the technology frontier. The evidence summarized here, however, points to a different explanation for the existence of the gap. Our explanation relates it to firms' low internal efficiency—as partially captured in Bianchi et al. (2008) regarding human resources—and to the use of sub-optimal innovation input mixes. Given the latter, firms are probably disregarding the existence of complementarities among them and missing the potential gains stemming from innovation diversification. Firms not taking advantage of the existence of complementarities among different types of innovation output may also explain the low frequency of firms focusing on TPP. Moreover, the evidence shows that the innovative productive processes obtained by Uruguayan firms have a perverse scale effect on labor productivity, thus highlighting a specific bottleneck in the innovative behavior of firms.

On the contrary, those firms that restrict innovation to processes generally combine productive with non-technological procedures, generating gains in their labor productivity growth that are almost twice the size of the return on innovation products. However, if focusing on non-technical procedures, there is a deceleration of labor productivity relative to the impact of other types of output. Conversely, there are positive scale effects of innovative commercialization practices on the dynamics of productivity. The fact that the share of innovative firms that undertake innovation in commercialization processes is low suggests that a likely obstacle to firm performance faced by Uruguayan firms is the lack of optimal commercialization strategies. Data for 2006 further support the hypothesis, as it shows that an increasing number of firms that are able to establish cooperation agreements include the design of adequate commercialization practices among the issues of interest.

The relative lag shown by the innovation behavior of Uruguayan manufacturing industries is not the consequence of firms rarely engaging in innovation activities, but rather of the low degree of the innovative relevance generally attained. A partial explanation for this failure is related to the bulk of the innovation output obtained being related to processes. This behavior is probably linked to the goal sought by firms through innovation. Product innovation is mostly a means of increasing market share, while process innovation is intended to reduce costs while maintaining the scale and level of production. Thus, firms operating mostly in the local market tend to focus on process innovation, while exporting units are more prone to innovate in products.

An additional contribution of this research is its finding that many of the results reported in the existing literature—indicating no input-output relations and no returns to innovation in non-developed countries—are most likely the consequence of improperly specifying the mechanisms at work. Two major shortcomings relate to the joint treatment of processes and product innovation and to the failure to account for the differences in the degree of relevance of the output. Further still, doubt is cast on the robustness of the conclusions because the empirical studies lack a sample design correction, an omission shown here to crucially generate biases of significant size in many estimated parameters.

The main findings supported by the evidence can be summarized as follows:

- The decreasing time trend registered in the propensity to innovate among firms surveyed between 1998 and 2006 is mainly driven by small units and by non-national firms that had formerly focused on innovative products.
- Product-innovative firms diminish their share over time, due to large national units switching to process innovation. Conversely, the share of exporting and large, non-nationally owned firms specialized in innovative products increased.

- The lack of success in the activity cannot be considered a disincentive, since not only the majority of innovative firms do get an output, but the evidence also shows significant returns to innovation in terms of labor productivity.
- The anti-cyclical innovation behavior of small firms is the result of the strategies used by most units innovating in processes and of those non-national companies focused on the local market and innovating in products. The pattern is shared by large non-national exporting firms that innovate in products and large national non-exporting companies innovating in processes.
- Large enterprises, especially if they are exporters, form the core of innovative firms with respect to the international market. They are concentrated in a few industries—food, textiles, chemicals and machinery and equipment.
- Most firms innovate in processes to reduce costs with the aim of overcoming a decline in local demand, given their inability to achieve product innovation at the international level.
- Except for large foreign exporting companies, efforts are concentrated on selling novel products in the international market.
- Characteristics promoting firms' engagement in innovation activities are: a high level of internal efficiency, high skill and productivity levels of its workforce, a physical capital-intensive technology, a large scale of production, establishing links with NIS agents for information, and belonging to international networks that would facilitate their access to high-level technologies. These findings are borne out by the increasing trend towards a higher professionalization of innovation activities, both in terms of sources of information and of financing institutions. The exporting intensity of sales is negatively related to the propensity to innovate, possibly due to the inability of those firms to attain the internationally required level of innovation relevance.
- The evidence suggests that firms are disregarding some potentially key factors when investing in innovation inputs. The financial effort needed would be reduced if firms diversified the input mix used, increasing the share of R&D in total investment and relying less on physical capital as a main innovative input. This pattern may be also related to the degree of competitiveness of the

market in which firms operate, the weight assigned to research and engineering and industrial design being larger the more concentrated the market. This result is also in line with the fact that firms are less prone to innovate when the main obstacles stem from the market.

- Firms related to NIS agents are mainly looking for technical assistance and information, no matter their size or their innovative character. It is interesting to note that this behavior is increasing over time for small firms, while large enterprises have started to progressively associate with NIS agents looking for support in their training programs. This is consistent with the increase in the number of large firms that switched from process to product innovation. Moreover, firms that have established a link to the NIS, particularly when seeking collaboration in their R&D effort, impact the enterprises' ability to generate a more relevant innovation output. Thus, the result discounts a failure of the NIS in terms of the quality of the advice provided.
- Financing is surprisingly not among the most important objectives sought through links with NIS agents, either for large or small firms. The behavior of small firms, however, suggests that they are unable to fully access or take advantage of the NIS assistance. Although they claim that the lack of financing is an important obstacle to innovation, firms do not relate to NIS agents pursuing that goal. The fact that financial institutions have played an increasingly relevant role in supporting innovation activities points to a more professionalized approach to innovative practices. This may be because they are assigned a more significant role in the economic performance of the firm.

Given the above, policy actions should be focused on generating and disseminating relevant information on the relative effects of different kinds of innovation activities and on defining an optimal input mix in order to obtain the needed type of innovation output. The generation and publication of this type of information should be done by existing public research institutions. An alternative recommendation is to focus on easing the channels through which information is transmitted from public and private agents devoted to research to the relevant productive actors. Furthermore, and given that process innovation is the most relevant type of innovation output to boost productivity, the evidence suggests that Uruguayan firms are below their optimum efficiency level, since they are unable to leverage their product innovation. This leads to the recommendation that NIS agents should assist local firms in improving their internal procedures before pursuing other type of innovation activities. Policy actions should therefore be aimed at introducing incentives for improving process efficiency at the firm level before supporting any other innovation activities, such as investing in innovative capital or R&D. One could think of developing conditioned loans for firms, compelling them first to adjust and improve their processes before granting financing devoted to product innovation. A further bottleneck is related to the inability of firms to develop adequate commercialization strategies, an obstacle that public agents can help to overcome, for example by easing the linkages between national entrepreneurs and foreign potential clients through the commercial representatives in foreign countries.

In order to analyze the innovation behavior of Uruguayan firms, the research summarized here has made use of a simplified theoretical framework that prevents the capture of several dimensions that may be key for thoroughly understanding the mechanisms at work. One issue is the need for more sophisticated analysis of the rationale underlying the decision to innovate, linking it to the overall performance of the firm. The issue should not be disregarded in the case of Uruguay given the goals pursued with innovation, as declared by the firms themselves. Secondly, future empirical models should explain how innovative inputs are combined to obtain each type of output by means of the so-called knowledge production function. In order to accurately quantify the magnitude of the actual returns on innovation, investigating the mechanisms through which the diverse innovation processes and products interact to generate the additional production factor would be highly recommended. Finally, more work should be done on the use of methodologies that fully account for the actual sampling models and other characteristics of the available information sets. The results obtained here reveal that the effect of neglecting this dimension of the analysis is significant. A key facet relates to the modeling of the process as a simultaneous rather than a recursive system, also incorporating the dynamics underlying innovation practices. These dynamics are linked both to analyzing the existence of an optimum time path depending on the input and output mixes observed, and to the eventual productivity gains in terms of the innovation output itself.

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Appendices

Appendix A

Table A.1 – Descriptive Statistics

Variables - All firms	**Mean**	**Ds.Std**	**Min**	**Max**	**Obs.**
Total Innov. Exp./Sales (log)	-4.297	1.684	-9.291	0.060	239
Innovation output (log)	1.499	0.761	0.288	3.586	240
Productivity Growth	0.196	0.801	-3.299	5.086	494
Engineers/Professionals firm	0.225	0.288	0	1	494
Export intensity	0.216	0.337	0	1	494
Share of foreign capital	0.132	0.332	0	1	494
Avg.labor productiv.- (log)	0.012	0.914	-3.694	5.095	459
Capital/Labor - (log)	0.012	0.801	-3.299	5.095	455
Labor - Rate of Growth	0.138	0.351	-2.833	1.804	494
Capital/Labor - Rate of Growth	12.376	1.159	7.007	17.225	494
Productive capacity - % use	0.760	0.221	0.010	1	494
IICI2	0.216	0.404	0	1	494
Product innovative firms	**Mean**	**Ds.Std**	**Min**	**Max**	**Obs.**
Total Innov. Exp./Sales (log)	-4.016	1.545	-8.148	-1.370	134
Innovation output (log)	1.874	0.607	0.888	3.586	136
Productivity Growth	0.101	0.758	-1.386	4.465	136
Engineers/Professionals firm	0.326	0.289	0	1	136
Export intensity	0.256	0.338	0	1	136
Share of foreign capital	0.217	0.405	0	1	136
Avg.labor productiv.- (log)	12.818	1.170	7.007	17.225	136
Capital/Labor - (log)	12.886	1.114	9.353	15.731	131
Labor - Rate of Growth	0.241	0.257	-0.422	1.184	136
Capital/Labor - Rate of Growth	0.065	0.737	-1.737	2.596	131
Productive capacity - % use	0.771	0.205	0.010	1	136
IICI2	0.619	0.306	0	1	136
Only Process innovative firms	**Mean**	**Ds.Std**	**Min**	**Max**	**Obs.**
Total Innov. Exp./Sales (log)	-4.632	1.811	-9.292	0.060	101
Innovation output (log)	1.009	0.659	0.288	2.903	104
Productivity Growth	0.082	0.672	-2.818	1.938	104
Engineers/Professionals firm	0.294	0.289	0	1	104
Export intensity	0.261	0.366	0	0.990	104
Share of foreign capital	0.165	0.357	0	1	104
Avg.labor productiv.- (log)	12.725	0.910	10.606	14.920	104
Capital/Labor - (log)	12.683	1.247	9.168	15.488	102
Labor - Rate of Growth	0.152	0.339	-1.022	1.804	104
Capital/Labor - Rate of Growth	-0.046	0.819	-2.504	3.208	102
Productive capacity - % use	0.793	0.191	0.300	1	104
IICI2	0.766	0.286	0	1	104

Table A.2. List and Definition of Independent Variables

Variable Name	Definition
R&D - Dummy	Binary variable equal to 1 if the firm invested in R&D
K+H+S - Dummy	Binary variable equal to 1 if the firm invested in Capital, Hardware or Software
Training Programs - Dummy	Binary variable equal to 1 if the firm invested in Training Programs
EID+CS+TT - Dummy	Binary variable equal to 1 if the firm invested in Engineering & Industrial Design, Technology Transfers or Consultancy Services
Innovation in Products– Dummy	Binary variable equal to 1 if the firm obtained an innovative product
Only Inn. Processes– Dummy	Binary variable equal to 1 if the firm only obtained innovative processes
Only Inn. Non-product. Process– Dummy	Binary variable equal to 1 if the firm only obtained non-productive innov.processes
Inn. in Productive Process– Dummy	Binary variable equal to 1 if the firm obtained productive processes
Inn. in Commercialization Process– Dummy	Binary variable equal to 1 if the firm obtained commercialization processes
Inn. in Organization Process– Dummy	Binary variable equal to 1 if the firm obtained organization processes
Size: 20-49 workers – Dummy	Binary variable equal to 1 if the firm's workforce is between 20 and 49 workers
Size: 50-149 workers – Dummy	Binary variable equal to 1 if the firm's workforce is between 50 and 149 workers
Size: 150 workers & more – Dummy	Binary variable equal to 1 if the firm's workforce is above 150 workers
Foreign ownership – Dummy	Binary variable equal to 1 if the firm is partly or fully foreign owned
Share of foreign capital (%)	Percentage share of foreign capital in total capital
Full Foreign ownership – Dummy	Binary variable equal to 1 if the firm is fully foreign owned
Economic group – Dummy	Binary variable equal to 1 if the firm is part of a wider group of firms
Export – Dummy	Binary variable equal to 1 if the firm is an exporter (EAS)
Full export – Dummy	Binary variable equal to 1 if the firm is exports 100% of its production (EAS)
Exports over sales (%)	Proportion of exports over total sales in 2006 pesos (EAS)
Capital/Labor - Rate of Growth	Log growth of capital-labor intensity from previous to current period (EAS)
Labor - Rate of Growth	Log growth of employment from previous to current period
Avg.labor productiv.- 1 lag (log)	Log average labor productivity in previous time period (EAS)
Capital/Labor - 1 lag (log)	Log of physical capital-labor intensity in 2006 pesos (EAS)
Engineers/Professionals firm (%)	Percentage of engineers in the total number of the firm's employed professionals
Productive capacity - % use	Percentage usage of the firm's installed capacity
Formal R&D unit - 1 lag – Dummy	Binary variable equal to 1 if the firm had a formal R&D unit in the previous period
IICI2	Innovation Input Concentration Indicator as defined in Section 4.2
Obstacles: firm - Dummy	Binary variable equal to 1 if the firm considered any firm related obstacles as highly affecting its developing innovation activities[1]
Obstacles: macro - Dummy	Binary variable equal to 1 if the firm considered any macroeconomic obstacles as highly affecting its developing innovation activities[2]
Obstacles: market - Dummy	Binary variable equal to 1 if the firm considered any market related obstacles as highly affecting its developing innovation activities[3]
Information High Relevance - Dummy	Binary variable equal to 1 if the firm marked a source of information as being highly relevant for its innovation activities[4]
Financing: External resources - Dummy	Binary variable equal to 1 if the firm financed its innovation activities through external financing sources
Financing: Related agents (%)	Percentage of resources stemming from related agents used for innovation activities
Financing: Public sector (%)	Percentage of resources stemming from public sector used for innovation activities
Financing: Banks (%)	Percentage of resources stemming from banks for innovation activities
Financing: International (%)	Percentage of resources stemming from international institutions for innovation activities
Link with NIS agents – Dummy	Binary variable equal to 1 if the firm had a link with any NIS agent
Link: Technical assistance - Dummy	Binary variable equal to 1 if the firm had a link with NIS agents seeking technical assistance
Link: R&D – Dummy	Binary variable equal to 1 if the firm had a link with NIS agents seeking R&D
Link: Training – Dummy	Binary variable equal to 1 if the firm had a link with NIS agents seeking training
Link: Information - Dummy	Binary variable equal to 1 if the firm had a link with NIS agents seeking information

[1] The listed obstacles in the IS are: Scarce specialized labor; Organizational rigidity; Innovation associated risks; too wide time horizon to obtain returns on innovation. [2] The listed obstacles in the IS are: Small market size; Scarce technological opportunities in the sector to which the firm belongs; Difficulty accessing financing sources; Scarce cooperation opportunities with other firms and institutions; Easy replicability of product by competitors. [3] The listed obstacles in the IS are: Insufficient information on markets; Insufficient information on technological opportunities; Insufficient/failing of public policies promoting Science and Technology; Scarce development of institutions related to Science and Technology; Inadequate physical infrastructure; Insufficient guarantees in Intellectual Property Rights; Macroeconomic instability.[4] The listed sources in the IS are: Internal information sources; Vendors; Clients; Related firms; Competitors; Universities, Technological R&D centres (public or private); Consultants and experts; Fairs and conferences; Journals; Databases; Internet; Parent company.

Appendix B - Estimation Effects of Ignoring Sample Design Corrections

Table B.1 Innovation Propensity and Innovation Intensity Equations

	Innovation Propensity (dy/dx)	**Innovation Propensity (dy/dx)**	**Innovation Intensity**	**Innovation Intensity**
Variables	**Model 1[1/]**	**Model 2[2/]**	**Model 1[1/]**	**Model 2[2/]**
R&D - Dummy	------------	------------	0.6434***	0.8384***
K+H+S - Dummy	------------	------------	1.9141***	2.4659***
Training Programs - Dummy	------------	------------	0.0509	0.2760
EID+CS+TT - Dummy	------------	------------	0.7756***	0.4416*
Size: 20-49 workers – Dummy	**0.1745****	**0.1101**	-0.7176	0.7110
Size: 50-149 workers – Dummy	0.2608***	0.2125**	**-1.4452****	**-0.6137**
Size: 150 workers & more – Dummy	0.3753***	0.4024***	**-1.4518***	**-0.2417**
Foreign ownership- Dummy	0.0880	0.2150	-1.3270***	-1.5979***
Multinational Firm– Dummy	-0.0074	-0.1158	1.1842**	1.3401***
Economic group – Dummy	**-0.0565**	**0.1844*****	0.4779	0.5517
Export – Dummy	------------	------------	-0.3601	-0.2325
Full export – Dummy	------------	------------	**1.0944***	**0.9268**
Exports over sales (%)	**0.0748**	**-0.1092***	------------	------------
Avg.labor productiv.- 1 lag (log)	**0.0459**	**0.1347*****	-0.1340	-0.3412
Capital/Labor - 1 lag (log)	**0.0296**	**0.0663*****	0.0801	0.0826
Engineers/Professionals firm (%)	0.2442**	0.2078**	-0.3875	0.2793
Productive capacity - % use	**0.0844**	**0.2255***	------------	------------
Formal R&D unit - 1 lag – Dummy	0.0499	-0.0067	0.4346*	0.5526*
IICI2	------------	------------	1.1861**	1.7072***
Obstacles: firm - Dummy	0.0442	0.0658	------------	------------
Obstacles: market - Dummy	**-0.1074**	**-0.2633*****	------------	------------
Obstacles: macro - Dummy	-0.0291	0.0385	------------	------------
Information High Relevance - Dummy	0.1678**	0.1300**	------------	------------
Financing: External resources - Dummy	------------	------------	0.4685	0.3955
Financing: Related agents (%)	------------	------------	-0.3028	-0.3337
Financing: Public sector (%)	------------	------------	1.3701	1.8258
Financing: Banks (%)	------------	------------	-0.3543	0.0690
Financing: International (%)	------------	------------	-2.3024***	-1.6920**
PSUs/Strata[3/]	457/----	457/93	457/----	457/93
Censored Observ.	------------	------------	225	225
F(k,N-k) [4/]	52.73***	15.71***	143.9***	23.40***
Rho[5/]	**-0.898****	**-0.4233**	------------	------------

Notes: Bold type denotes coefficients that are statistically significant in one model and non-significant in its counterpart.
[1/] "Model 1" refers to the equation estimated with HCSE (White, 1980) and no sample design correction.
[2/] "Model 2" is the same equation but including the sample design correction.
[3/] "PSUs" are the primary sampling units; "Strata" are those defined in the sampling model used in the surveys.
[4/] "F-statistic" signals at the overall significance of the model/ Chi-2 in column 3.
[5/] "Rho" refers to the estimated correlation coefficient between the main equation and the selection function.

Table B.2 Innovation Output and Productivity Equations

Variables	Innovation Output Model 1[1/]	Innovation Output Model 2[2/]	Productivity Growth Model 1[1/]	Productivity Growth Model 2[2/]
Total Innov. Exp./Sales (log)	0.1312	0.0909***	------------	------------
Innov. Output – Products (log)	------------	------------	0.0369**	0.0486***
Innov. Output - Only Process (log)	------------	------------	**0.0451**	**0.1328*** **
IICI2	-0.3618**	-0.3807**	------------	------------
Innov. Products– Dummy	------------	------------	-0.0115	0.1208
Only Inn. Processes– Dummy	------------	------------	0.0509	-0.1226
Only Inn. Non-product. Process– Dummy	------------	------------	**-0.0577**	**-0.5510** **
Inn. Product. Process– Dummy	------------	------------	**-0.0546**	**-0.2905** *
Inn. Commerc.. Process– Dummy	------------	------------	0.2029*	0.2317**
Inn. Organisat.. Process– Dummy	------------	------------	**-0.2029** **	**-0.1974**
Capital/Labor - Rate of Growth	------------	------------	0.0972**	0.0771*
Labor - Rate of Growth	------------	------------	-0.2743**	-0.2758**
Size: 20-49 workers – Dummy	**-0.2839**	**-0.6088*** **	-0.0478	0.1202
Size: 50-149 workers – Dummy	**-0.1928**	**-0.3782*** **	**-0.0048**	**0.2274** **
Size: 150 workers & more – Dummy	**-0.0247**	**-0.2846** **	**-0.0534**	**0.1865** *
Engineers/Professionals firm (%)	0.2124	0.0477	------------	------------
Formal R&D unit - 1 lag – Dummy	0.3652***	0.4591***	------------	------------
Share of foreign capital (%)	-0.3294	-0.2656	------------	------------
Multinational Firm– Dummy	0.4786**	0.3987**	------------	------------
Full exporter – Dummy	0.5841**	0.6277**	------------	------------
Exports over sales (%)	0.1323	0.1133	------------	------------
Avg.labor productiv.- 1 lag (log)	------------	------------	-0.4128***	-0.4424***
Capital/Labor - 1 lag (log)	**0.0422**	**0.0907*** **	------------	------------
Productive capacity - % use	------------	------------	**0.1052**	**-0.2600** *
Link with NIS agents – Dummy	0.3162*	0.4185***	------------	------------
Link: Technical assistance - Dummy	**0.1870** *	**0.1020**	------------	------------
Link: R&D – Dummy	0.2030*	0.3246***	------------	------------
Link: Training – Dummy	-0.0137	-0.0350	------------	------------
Link: Information - Dummy	-0.0109	-0.0666	------------	------------
PSUs/Strata[3/]	233/---	233/69	453/---	453/93
F(k,N-k) [4/]	9.07***	52.73***	9.33***	42.48***

Notes: Bold type denotes coefficients that are statistically significant in one model and non-significant in its counterpart.

[1/] "Model 1" refers to the equation estimated with HCSE (White, 1980) and no sample design correction.

[2/] "Model 2" is the same equation but including the sample design correction.

[3/] "PSUs" are the primary sampling units; "Strata" are those defined in the sampling model used in the surveys.

[4/] "F-statistic" signals at the overall significance of the model.