To innovate or not to innovate?
The case of Uruguayan manufacturing firms[ϒ]

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Introduction

The literature devoted to the analysis of the underlying mechanisms restraining growth signals at low human capital endowments, insufficient provision of public goods, financial market failures, and shortcomings of the regulatory framework or overall business environment as most likely causes. A different and complementary explanation relates to private agents' innovation behaviour.

In the case of Uruguay, the rates of growth along 1960-2000 have been far from those expected at the technological frontier, so that the analysis stands as most in place. Relative to other Latin American countries, the Uruguayan institutional framework is adequate for investors, while its population schooling level is high enough to discard the existence of human capital restrictions. Focusing on the 90s, the most salient feature underlying its meagre performance is the extremely low level of investment demand (Bértola *et al*., 2005; Hausmann *et al*., 2005). The low returns to capital have usually been associated to macroeconomic factors, such as a high degree of volatility of public policies, especially those related to the exchange rate and tax levels, and the sensitivity of the economy to its neighbours' economic performance. Nonetheless, these causes are not necessarily a comprehensive explanation of the phenomenon. Thus, concerns have moved towards analysing the country's performance in terms of innovation activities, the level of resources invested in R&D and other innovation activities within existing firms being scarce, while the so-called 'self-discovering efforts' far from widespread. Risk-averse agents, difficult access to financial aid, inadequate information channels and insufficient public policies directly supporting innovation activities are some of the suggested causes.

Generating 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 in the country. Consequently, institutions devoted to the analysis of the expected impact of innovation on different areas have been recently created. The current institutional framework for the design of policies seeking to promote innovation activities is thus an additional motive for identifying the mechanisms underlying the innovative behaviour of firms. The research summarised below attempts to be a contribution in that direction.

The state of the art

The literature on the links between innovation practices and economic growth can be traced back to 1957 with the work done by Solow. The main obstacles faced by empirical researchers at the time were linked to the measurement of technical progress, which was surmounted by estimating it as a residual factor. Later on, innovation has been proxied by means of the level of expenditure devoted to R&D or else as its share in total revenue. Considered as an additional production factor, its coefficient in a total productivity equation would account for the returns to innovation. Before the 80s, most studies on innovation behaviour and technical change used aggregated data. Once firm level information started to be available, analyses were readily performed using microdata (surveys on the topics are found in Mairesse and Sassenou, 1991 and in Hall and Mairesse, 2006).

In the 90s, theoretical and methodological frameworks of higher complexity started to be used in empirical analyses. Crépon *et al*. (1998) is one of the earliest references, being their theoretical setting in line with that proposed by Griliches (1979) and used in Pakes and Griliches (1984). The authors showed that the returns to innovation as estimated by previous models suffered from significant biases arising from the incorrect inclusion of R&D expenditure in the productivity equation, the actual production factor to be taken into account being the output that resulted from having invested in R&D instead. They assimilated the mechanism through which innovative inputs are transformed into an innovation output to that of a standard production technology, its key input being R&D, giving rise to the so-called *knowledge production function*. These two behavioural equations were signalled as conditional on two additional *prior* stages related to the decision to innovate itself and to the determination of the amount of resources to be devoted to the activity. As such, the original paper provided with a rationalisation of the innovation behaviour of firms as a sequential integrated process, formalised in what came to be known as the *CDM model*. The predictions stemming from the model refer to firm size, market share and diversification of production positively influencing the firm's propensity to innovate and its intensity. Demand-pull and technology-push variables are assumed to play a positive role on the intensity of innovation that in turn

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determines the value of the innovation output. The latter is expected to enhance labour productivity. The comprehensive character of the theoretical model and the solutions proposed for its empirical implementation, derived in its soon becoming the most widely used benchmark for the applied research afterwards carried on.

Most of the studies performed for countries in Europe and Asia within the CDM framework, as well as for US and Canada, obtain results that are consistent to those predicted by the model[1]. Studies analysing the comparative performance among countries further conclude that there are no significant differences when controlling for country specific effects, even if pooling countries with different levels of development[2].

Although recently catching up, the research on innovation impacts on firm performance in Latin America is still scarce[3].The results obtained, however, are not always in line with the CDM's predictions, as returns to innovation are not found to be significant while the size of the innovation effort would play no role in the input-output equation. In the case of Uruguay, no research following these lines has been yet carried on. However, it has been suggested that likely underlying causes of the poor innovative behaviour of Uruguayan firms are linked to the absence of economic incentives, the scarce public support, and the lack of cooperation among firms[4]. It has also been noted that a high technical level of the firm's workforce is a key requirement for firms successfully undertaking innovation activities (Bianchi *et al.*, 2005).

The consistency of conclusions drawn for developed countries and the differing results obtained for Latin America economies motivates a thorough analysis of the applicability of the CDM framework to the latter. One of the likely explanations is related to these countries devoting a large extent of their innovation efforts to processes rather than products, rendering indicators based on innovative sales inadequate proxy variables. Further, the focus set on R&D as the only innovation input may also be unsuitable given the low frequency of firms investing on R&D. These hypotheses are supported by Raffo *et al.* (2007) who identify positive effects of innovation both on the input-output equation and on the productivity function when including those dimensions into the analysis. The authors further state that the positive impact of NIS agents and of international partners on the innovation behaviour of Latin American is greater relative to European firms. Other authors have also recently investigated the role of innovation processes separately from products. Their findings suggest that, at least in the short run, innovation processes have a higher impact on firm productivity than that of products, the latter found to be even non-significant in some cases[5].

Analytical Framework – the CDM model

The CDM model includes four basic equations – the propensity to innovate; the intensity of the innovation effort; the knowledge production function; and the productivity equation:

$$\text{If } g_i^* \geq C_i^* \Rightarrow g_i = \boldsymbol{X}_{0i}\boldsymbol{\beta}_0 \quad ; \quad \text{if } g_i^* < C_i^* \Rightarrow g_i = 0 \qquad (1)$$

$$\text{If } g_i = 1 \Rightarrow k_i = \boldsymbol{X}_{1i}\boldsymbol{\beta}_1 \quad ; \quad \text{if } g_i = 0 \Rightarrow k_i = 0 \qquad (2)$$

$$\text{If } k_i \neq 0 \ (g_i = 1) \Rightarrow t_i = k_i\,\alpha + \boldsymbol{X}_{2i}\boldsymbol{\beta}_2 \quad ; \quad \text{if } k_i = 0 \ (g_i = 0) \Rightarrow t_i = 0 \qquad (3)$$

$$lnq_i = \sigma\sum t_i + \boldsymbol{Z}_i\boldsymbol{\lambda} + \boldsymbol{X}_{3i}\boldsymbol{\beta}_3 \quad \text{or else:} \quad \Delta lnq_i = \sigma t_i + \boldsymbol{\lambda}'\Delta ln\boldsymbol{Z}_i + \boldsymbol{\beta}_3'\Delta ln\boldsymbol{X}_{3i} \qquad (4)$$

Where: g^*_i is a latent variable denoting firm i's propensity to innovate; C^*_i is a certain threshold interpretable as a decision criterion to innovate; so that whenever g^*_i exceeds C^*_i it would thus be possible to observe innovative activities performed by firm i, denoted as g_i. The size or intensity of the innovation effort is captured by k_i; t_i is the innovation output; and q_i is the log of labour productivity, so that Δlnq_i refers to its rate of growth. The vectors $\boldsymbol{X}_{0i}$, $\boldsymbol{X}_{1i}$ and $\boldsymbol{X}_{3i}$ include firm, sector and macroeconomic characteristics, while factors of production are gathered in vector $\boldsymbol{Z}_i$.

The empirical implementation of the theoretical CDM model has encountered several obstacles that have frequently been sorted out by using highly simplified estimable models, limiting the scope of the conclusions drawn from them, especially those related to policy recommendations.

A first issue refers to neglecting the existence of other innovation inputs apart from R&D activities. It may be argued that accumulated R&D constitutes the innovative 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 proportion of innovative practices. Novel IT tools or certain physical capital, on the other hand, may be considered as innovation inputs although of an intrinsically different nature.

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 output, a further challenge relates to the

[1] See Arundel *et al*. (2003) for an extensive survey.
[2] Griffith *et al*. (2006); Janz *et al*. (2004)
[3] Some notable exceptions are López and Orlicki (2006) for Argentina; Goedhuys (2007) for Brazil; Benavente (2004) for Chile; Hernandez (2005) for Colombia and Pérez *et al*. (2005) for Mexico. A survey can be found in Hall and Maffioli (2008).
[4] Bianchi and Gras (2005); Hausmann *et al*. (2005); Arocena and Sutz (2008); Hall and Maffioli (2008).
[5] Huergo and Jaumandreu, 2004; Lee and Kang, 2007; Masso and Vahter, 2008.

specification of the path through which innovation inputs are combined to obtain each type of output. If complementarities exist, adding up the resources spent in different inputs would be an incorrect measure of the resulting overall innovation input and of its role in generating innovation output, so that the analyses performed using the intensity of innovation/knowledge production function model that ignore complementarities effects are most likely to be misleading. 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. As first step in this direction, we here define an indicator of the degree of diversification of the expenditure devoted to innovation activities. The indicator is defined as a Herfindahl-type index, the proportion of total expenditure assigned to each input being used as weights.

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 innovation output by innovative 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 how inputs are transformed into output, substituting it by modelling the odds of obtaining an innovation output conditional on the resources invested in innovation inputs[7].

Regarding the analysis of the effects of innovation on firms' performance, the inclusion of innovative processes has been restricted to scale effects. In the case of products, the returns to innovation have also been estimated by using innovative sales as a proxy variable. However, since the variable is 0 not only when no innovation is done but also when only processes are obtained, no returns to process innovation can be measured, while misleading results regarding the estimated marginal effects of product innovation on productivity may also be generated. The consequent disregard of the role played by innovation processes for analyses performed in less developed countries as already discussed might be extended to developed economies when facing adverse long lasting shocks. The underlying reason is linked to the fact that under such circumstances, firms generally display cost reduction strategies, the generation of novel productive, commercialisation and organisational procedures being one suitable means to attain the mentioned goal.

We here propose the use of an indicator that accounts for the relevance of the innovation output, thus resulting in an approximation to its intrinsic value while capturing the existent cross section variability ignored by binary variables. Further, being calculated separately for each type of innovation output, it also serves to surmount the unbalanced role that previous research has assigned to process innovation, restricting its impact on productivity to scale effects or even completely ignoring its influence, while not analysing the mechanisms linking innovation inputs to innovative processes. The relevance of the output is here assimilated to its level of novelty being just the firm, the local or the international market.

The behaviour of innovative firms: inputs and output

A large extent of applied research decides to exclude some of the different types of innovation input/output from their analyses. In the case of innovation output, most of the applied work refers to new products and innovative production processes, while R&D has been the most studied innovative input. In the case of Uruguay, however, the omission of any category of innovation input or output is not in place given the particular innovation practices pursued by manufacturing firms. Not differentiating among types does not seem advisable either, as the diverse mixes chosen by firms are most likely to be informative. The complexities that would be introduced in the econometric models with the available detailed classification included in the surveys, forced us to follow an intermediate strategy, grouping types of output and input into two and four categories, respectively. The resulting types of input considered are *R&D* (both internal and external); Physical Capital, Hardware and Software (*K+H+S*); Training Programmes, including those directed to managers (*TP*); and Engineering & Industrial Design, Technology Transfers and Consultancy Services (*EID+TT+CS*). Output categories refer to *Products*, accompanied or not by innovation processes; and *Only Processes*, no matter they relate to production, commercialisation or organisational practices. The resulting frequency of firms is shown below in Table 1.

Most innovative firms include physical capital, hardware and software among the inputs in which to invest, being training programmes the second preferred choice. Investing in just one innovative input is quite rare, particularly if restricted to R&D, while investing is the least observed category.

Innovation processes are the most frequent type of innovation output obtained, as around 90% of firms innovate in at least one process[8]. The figures are still high if restricted to each type of innovative process, being those related to production the category with the highest proportion of firms. Interesting enough is that the pattern of the data suggests that there was a switch in firms' innovation goals after the economic crisis from product to only process innovation.

[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.

[8] Although the proportion of product innovative firms is 60%, there figure is overestimated for various reasons, e.g. those reporting innovative sales are 7% less than those answering 'yes' to the initial question on them having got an innovative product or not, while all other questions on the sort of innovative output obtained were answered relative to processes and not products.

Table 1: Distribution of firms by innovation input and output 1998 – 2006 *(% firms)*

	1998-00	2001-03	2004-06		1998-00	2001-03	2004-06
Total firms	100	100	100	**Inn. firms with output**	97	99	98
Innovative firms	67	55	49	**Production Processes**	83	84	71
R&D	55	52	44	**Organisational Procs.**	66	68	43
K+H+S	86	80	82	**Commercialisation Procs.**	53	55	24
EID+TT+CS	48	50	37	**Processes**	96	95	89
TP	69	67	69	**Products**	64	64	57
Only R&D	2	4	3	**Products & Prod. Procs.**	10	13	5
Only K+H+S	14	13	17	**Prods. & Non-Prod. Procs.**	5	2	5
Only EID+TT+CS	2	2	2	**Only Processes**	36	36	43
Only TP	3	6	6	**Only Production Procs.**	10	7	18
				Only Non-Prod. Procs.	8	9	13
				Only Products	4	5	11
All Inputs	25	23	17	**All Outputs**	33	34	11

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

From the above, it can be stated that the innovation behaviour of manufacturing firms in Uruguay is more intensive in processes than in products, obtained by means of investing mainly in physical capital and training programmes for their employees. The most noteworthy result, however, relates to most firms obtaining a combined innovation output, both when new products are involved or not, by also combining inputs. This stylised fact thus strongly suggests the existence of complementarities among inputs and types of output. Nonetheless, the output mix most frequently analysed in the literature – products and production processes (TTP) – is surprisingly among the least observed (9% on average). This result supports the hypothesis of developed and non-developed countries displaying intrinsically different innovation behaviours.

The share and number of innovative firms steadily decreases along the period. The trend responds mostly to the evolution observed among firms with less than 50 employees, as the decline in their share of total firms is outdone by that of innovative firms (see Cassoni and Ramada, 2009a for a discussion). Nonetheless, the comparative analysis of the relevance of the innovation output obtained according to size shows that international market level innovation output is concentrated among large firms in a significantly greater proportion relative to that in local market or firm level innovation, where the share of small to medium size firms is non negligible. As such, the time trend characteristics should be studied in more depth (Table 2).

Table 2: Innovative firms by size and relevance of the innovation output 1998–2006 *(% firms)*

Relevance of Output		19 & less	20-49	50-149	150 & more
Firm Only	**2000**	10	33	34	22
	2003	9	30	24	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
Total	**1998**	9	28	39	24
	2003	10	33	34	23
	2006	6	23	40	31

Source: Innovation Surveys 1998-00; 2001-03, 2004-06; ANII/DiCyT /INE.

Interesting differences arise when analysing the composition of inputs according to the innovation output obtained by firms – products and only processes – classifying them according to destiny of sales; ownership; size; and economic sector (Table 3). Manufacturing innovative firms in Uruguay are concentrated in a few industries – Food, Textiles, Chemicals and Machinery & Equipment[9]. These four sectors account for around 75% of firms obtaining innovative outputs in products and processes; being the figure 80% if considering firms that innovate just in products and 70% when restricted those innovating only in processes. Characteristics shared by most firms belonging to the above sectors are them being exporting units, with and export intensity over 40%, owned by national entrepreneurs. The extent of international exposure is high for all industries and incresing in

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

time. On the other hand, the export intensity of these firms may explain the differentiated behaviours observed along the economic cycle (see Cassoni and Ramada, 2009a).

Table 3 – Inputs mix by type of innovation output and firm characteristics *(% firms investing in each 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
National 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-National 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 & 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 & less 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

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

The frequency of firms innovating in each of the 4 defined inputs is high and of similar magnitude for product innovative firms, suggesting a high average diversification of innovation expenditure among them. Only processes innovative firms, on the contrary, show a significant gap in their frequency depending on the input being K+H+S and TP or R&D and EID+TT+CS. Investment in R&D is procyclical and expenditure in TP countercycilcality for product innovative firms, while those innovating only in processes display a less related to the business cycle strategy. If classifying firms in exporting firms and fully domestic market oriented firms, there are no differences 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 behaviour shared also by firms getting 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 TP and EID+TT+CS. Contrarily, non-exporting firms are countercyclical on knowledge intensive inputs, i.e. in R&D and in EID+TT+CS, and procyclical on K+H+S and training. Still, the most salient difference between firms selling in the international or local markets is that investment in knowledge intense inputs is a lot more frequent among exporters. It can thus be stated that whenever firms operate in more competitive markets, they use a mix of innovative inputs that give a more important weight to research and design than when restricted to the local market, while they are a lot more protected from 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 in innovative K+H+S and in TPs, no matter the type of innovatition output obtained. In 2006 the picture changed slightly, as more non-national product innovative firms started investing in all inputs, catching up with the percentages observed among national 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 national firms focused only in processes. The trends observed are undoubtedly linked to the behaviour above signalled of the largest firms starting to innovate only in processes, together with the observed changes in the 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, TP and K+H+S. If only innovating in processes, the weight of TP increases while that of R&D decreases, a result that was quite expected.

A final dimension that is worth describing refers to the subjective view of firm's managers with respect to the role of agents associated to the activity, such as public institutions, NIS actors or other economic agents linked to the firm in diverse ways (competitors, suppliers, related enterprises, etc.), as wel as their opinion on which are the obstacles faced, the objectives pursued and the impacts obtained from innovation practices.

All firms invest in innovation inputs aiming at reducing costs, although large units also seek to increase their products' quality and maintaining or increasing their market share. Environmental concerns and related issues are not a goal for at least 60% of innovative firms, no matter their size. The motivations behind innovative activities are consistent with the impact they declare to obtain from innovative practices, which are mainly related to lowering labour costs by means of increasing the firm's production capacity and by maintaining and/or increasing their market share (Cassoni and Ramada, 2009a).

Firms related to NIS agents are mainly looking for technological assistance and information, no matter their size or their innovative character. This behaviour is increasing in time for small firms. Large enterprises have also evolved towards associating with NIS agents looking for support in their training programmes. Surprisingly, financial aid is not among the most important objectives sought through these links, no matter the size of the firm. There has been a change in the firms' behaviour with respect to which type of agents to approach when looking for financial aid. While in 2000 related firms was declared the first choice, by 2006 financial agencies became the preferred option. When analysing the information sources used by innovative enterprises, internal sources are considered as the most important. However, establishing links with both general and specific knowledge-generating agents is an increasing practice. These facts point at a trend in time towards the professionalisation of the innovation activity and 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 publicised and communicated by public and private institutions. Furthermore, it is absorbing to note that neither the lack of talent availability nor the failure or poor development of public policies and technical institutions are among the main obstacles declared by firms, a result in line with Hausmann *et al.* (2005).

Indicators for innovation output and input diversification

Since innovative processes are the bulk of innovation activities in Uruguay as shown above, we are not using standard indicators in this research, under the hypothesis that they might even generate misleading results. We use the proposed alternative measures, instead. Assuming that an internationally innovation output is much more relevant than one relative to local market or firm level novelty, especially in a non-developed country, the weight is defined as the inverse of the share of firms that obtain a particular output and relevance among the total number of firms obtaining that output. As such, the indicator's lower bound is one and it is theoretically unbounded[10]. The theoretical upper bound in our sample is 2796, being 45 the actual maximum reached (Table 4). Descriptive statistics are summarised in Table 5[11].

Table 4 - Innovation Type and Relevance - Weights

Products		Organizational Process	
Firm	2,12	Firm	1,68
Local Market	2,89	Local Market	3,12
International Market	5,50	International Market	11,67
Productive Process		**Commercialization Process**	
Firm	1,73	Firm	1,29
Local Market	3,23	Local Market	5,80
International Market	8,91	International Market	19,40

Source: Innovation Surveys 1998-00; 2001-03 and 2004-06,0 ANII/DiCyT/INE.

Table 5 - Indices for Innovation Output - *Descriptive Statistics*

	Obs.	Mean	SD	Min	Max
OIOI All Output	828	7,59	7,04	1,288	45,485
OIOI Only Processes	776	6,10	6,34	1,288	39,985

Source: Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE.

As already mentioned, the degree of diversification of the input mix used by firms may have an impact on the likelihood of attaining an innovation output, its costs and its relevance level. We therefore use an indicator built as a normalized Herfindahl index using the expenditure in each type of input as a proportion of total expenditure as the weighting factor. The intuition behind using this indicator is to assert if a more concentrated effort with investment focused on few innovation inputs yields different results than a more diversified innovation effort,

[10] If all firms innovate at the firm level in only one type of output the index equals 1, while if only one firm gets internationally innovative output of the four types the maximum value of the weight is the number of firms.

[11] For a comparison and description of the above indicators' performance, please refer to Cassoni and Ramada-Sarasola (2009b).

investing across several areas. One could therefore hypothesise that a more diversified innovation effort across different types of input, especially those associated with R&D, should decrease the risk of not obtaining significant innovation results, in the same fashion diversification works for a financial portfolio. We construct three versions of the Innovation Input Concentration Indicator (IICI), taking into account all nine innovation inputs (IICI); the four categories here defined (IICI2); and a third indicator that is built excluding K+H+S in order to evaluate the effect of the most frequent choice among innovation inputs[12]. The descriptive statistics in Table 6 support our aggregation of inputs while the relative high frequency of K+H+S investment does not significantly alter the variability of data but it does increase the mean value obtained.

Table 6 - Innovation Input Concentration Indicator - *Descriptive Statistics*

	Obs.	Mean	Std. Dev.	Min.	Max.
IICI	2314	0,303	0,377	0	1
IICI2	2314	0,326	0,401	0	1
IICI3	2314	0,259	0,389	0	1

Source: Innovation Surveys 1998-00; 2001-03 and 2004-06, ANII/DiCyT/INE.

Econometric Results

Our econometric model is framed in equations (1) to (4). The variables included are the following:

- Propensity to innovate - g_i: equal to 1 if the firm invested in any innovation input in each 3-years period
- Size of the innovation effort - k_i: expenditure in innovation inputs over value of sales in the last year
- Innovation output – OIOI differentiating among products and processes
- Productivity growth - Δlnq_i: gross value added in 2006 pesos over total employment, difference of logs
- $\boldsymbol{Z}_i$: physical capital stock in 2006 pesos over employment; number of employees; differences of logs
- $\boldsymbol{X}_{0i}$; $\boldsymbol{X}_{1i}$; $\boldsymbol{X}_{2i}$
    - Firm level: size binary variables; percentage foreign capital participation in total firm's capital; binary variable stating if the firm belongs or not to a economic network or group; deviation of the share of professionals in total employment at the firm with respect to that prevailing in the sector; percentage of engineers among the firm's professionals; past average labour productivity; usage of productive capacity; past capital-labour intensity; binary variables accounting for the firm being a full exporting unit, a fully domestically oriented firm or if participating in both markets; binary variables stating if there is a formal R&D unit at the firm or not, in the current period and also along 1998 to 2006; IICI2; a set of variables accounting for obstacles perceived as high; sources of financial aid approached; links with diverse NIS agents that were considered of high relevance; and goals pursued when approching NIS agents
    - Sector level: concentration - value of sales of the 4 largest firms over the industry's total sales
    - Economy level: stage of the business cycle, defined as the 3 years average gdp growth centered in the current year; uncertainty, defined as rolling windows of the gdp variance along previous 5 years

Data used stems from the matching of the three Innovation Surveys performed in 1998-2000, 2001-2003 and 2004-2006 and the Annual Economic Activity Surveys along 1998-2006[13]. Establishments with less than 49 workers are selected using stratified sampling, while those hiring 50 workers and more are all included. The response rate is always higher than 90%, generally above 95%, with the exception of the stratum of the smallest firms in the first survey (88%). We work with sample data, given sampling expansors are representative of employment and growth dynamics but not necessarily in terms of the innovative behaviour of manufacturing firms[14]. We kept only firms for which data are available along the 10 years, the final dataset including 1482 observations corresponding to 494 firms[15]. Given the design of the sample, descriptive analyses are biased towards the behaviour of large firms.

We distinguish firms by size, according to the number of employees, and by economic activity according to the ISIC Revision 3 classification. In order to simplify the analyses, and taking into account that the number of units within classes is relatively balanced, we pool the original categories into twelve economic sectors and four size strata[16]. Two strata are defined for firms selected by stratified sampling – 19-and-less and 20-to-49 workers, although a few of them are also defined as certainty units because of representativeness issues. The other two strata include only firms of mandatory inclusion due to their size – 50-to-149 and 150-and-more workers.

[12] For a thorough description of the IICIs and a comparison of their relative performance, refer to Cassoni and Ramada-Sarasola (2009).

[13] We are very grateful to the Institute of Statistics and the National Agency of Research and Innovation (ANII) for their invaluable help.

[14] This hypothesis was confirmed by Susana Picardo, who was in charge of the Annual Industrial Survey in 1998.

[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 given the small size of the Uruguayan economy and of an adequate size in terms of the significance of the analytical results.

[16] Namely, Food; Beverage; Tobacco; Textiles; Wood; Printing; Chemical Products; Petroleum; Plastic & Rubber; Non-metallic minerals; Metal products; Equipment & machinery; Other manufacturing industries.

Regarding the statistical models specified, there exists selectivity bias linked to the design of the samples themselves as stemming from the sampling model used by the Uruguayan Institute of Statistics for the EAS, identical to that of the IS. We thus control for our sample design signalling strata and certainty sample units to define weights, as suggested in Fazio *et al.* (2008)[17]. We estimated the propensity to innovate model independently from the other equations due to our having information on the intensity of the effort also for those units for which it is equal to 0, using a probit model. The 5-equations model based on (2) to (4) and estimating (2) and (3) for products and only processes innovative firms separately, is estimated recursively, using IV and random effects in the knowledge capital equations and the predictors stemming from them in the productivity growth function. Estimation results are summarised in Table 7 below.

The propensity to innovate

According to our results, Uruguayan firms are more prone to innovate if they already have a formal R&D unit, the higher the engineers-to-professionals ratio among their employees, the higher their past labour productivity level and the greater the positive gap between the firms' workforce average skill level and that prevailing in the sector they operate in. Further triggering factors are the firm's ability to obtain relevant information from specific knowledge organizations – e.g. laboratories and technological centres – as well as having internal channels to capitalize in-house information or expertise. The decision to innovate is procyclical, being firm level characteristics perceived as the most impeding obstacles to innovate.

The evidence also suggests that neither risk aversion linked to market conditions or uncertainty levels regarding the macroeconomic entourage, nor the overall institutional framework, can be considered as negatively affecting firms' propensity to engage in innovation activities. 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, although there are no relative differences among size strata (see marginal effects reported in Table 7).

On the opposite, the capital intensity of the firm's technology relative to labour; its being a fully or a partially exporting firm or not; and the level of competitiveness domestically faced, do not have any incidence on the firm's decision to innovate. Being part of an economic network or group is not relevant either, consistent with the fact that nationally owned firms are more likely to engage in innovation than those totally or partially owned by foreign entrepreneurs.

The intensity of the innovation effort

Once the decision to innovate has been undertaken, the firm's technological characteristics related to capital-labour intensity and to the use of its installed production capacity have no influence on the extent of the innovation effort – i.e., the proportion of innovation expenditure in total sales' revenue – for any type of innovative firms[18]. Further, despite foreign firms are less inclined to innovate than national units, no differences are found regarding the magnitude of the financial effort afterwards displayed. As such, it cannot be stated that the national/foreign origin of firms, that was expected to generate differentiated technology and efficiency levels, implies a distinct relative behaviour regarding innovation. There is no evidence either on differences in risk aversion or in the ease of access to relevant information or technologies having any impact. This would contradict Raffo *et al.*'s findings on the matter, given the authors claim that having access to foreign networks, capital or technology is key for firms in developing countries to pursue innovation activities.

As already hypothesised, the larger frequency of process relative to product innovation observed among Uruguayan firms may explain the contradicting findings reported in the literature on various behavioural predictions. The leading role displayed by R&D expenditure for firms in developed countries cannot be assumed when analysing less developed economies. Consistent with this view, our model reveals that the innovation effort devoted to innovative activities by Uruguayan firms is lower the more concentrated is its investment in particular innovation inputs. The size of the effect in the case of firms innovating only in processes is almost three times larger than that observed in the case of units getting innovative products both exclusively or not. Moreover, firms focusing only on innovation processes are a lot more inclined to invest in physical capital and training, the frequency of those that invest in engineering design and in R&D substantially smaller.

Other things equal, the size of the effort is relatively smaller for firms that invest on R&D and for those that exclude innovative physical capital, hardware and software from the chosen innovation input mix relative. The effect is of similar magnitude for both inputs and among firms obtaining both types of innovation output. Consequently, it is apparent that diversifying the investment in innovation inputs when trying to obtain innovative processes should imply substantial gains in terms of the size of the effort. On the other hand, investing in training programmes implies a greater effort if aiming to obtain innovative products and processes, while the opposite holds for those aiming to obtain only innovation in processes.

[17] We ignore the survival selectivity bias present for large firms due to the complexities that would be introduced relative to having a subsample for which we cannot correct for such bias.

[18] For product innovative firms, however, using an 88% confidence level, the closer to full capacity usage the firm is, the smaller the size of the effort devoted to investing in innovation inputs. The result may be linked to the need of investing in non-innovative inputs in order to go on operating normally.

These results point at the use of differentiated strategies depending on the goal pursued, which is most probably associated to the relative cost of the diverse inputs *vis à vis* their expected return as perceived by entrepreneurs. However, the evidence signals that this perception might not be correct, as the estimated model reveals that the size of the effort would be lower if investing in R&D while a higher effort is needed if spending in physical capital, no matter the type of output obtained. On the opposite, when including training programmes in the chosen input mix, a larger effort would be observed for firms seeking to obtain innovative products, while for those pursuing to get only novel processes the overall innovation effort would decrease. These effects would be further magnified if the overall expenditure were highly concentrated.

The above difference between the degrees of the effort displayed by innovative firms depending on the output obtained is also reflected in other behavioural dimensions. First, in the case of process innovative firms the magnitude of the innovation expenditure is positively related to the technical level of the firm's workforce, measured by the share of engineers relative to all professionals. The firm's relative skill endowment with respect to the one prevailing in the economic sector it belongs, on the contrary, has no impact on the level of innovation expenditure. The opposite holds for firms innovating in both products and processes, where only the firm's deviation from the sectoral skill endowment will affect innovation expenditure, the firm's internal composition in absolute terms having no effect. However, for product innovative firms the pre-existence of an R&D formal unit within the firm implies a larger effort, possibly offsetting the effect of the share of engineers. For firms innovating only in processes, the relationship between innovation effort and size appears to be nonlinear, with medium to large size firms (with 50 to 150 workers) devoting a relatively smaller effort to innovation activities than the smallest and largest units in the sample. In the case of firms innovating also in products the relationship is linearly decreasing with size. As such, the result is pointing at a less tighter budget restriction for largest firms, both due to scale and to the relative ease of accessing to the credit market, but it also reveals that the intensity of innovation when intended to obtain novel processes exclusively is smaller within the largest firms.

Thirdly, being a fully exporting enterprise implies a higher innovative effort only for firms innovating in products, a result in line with them facing a high degree of competitive pressure not only in terms of relative prices but also in quality standards. The level of concentration of the corresponding local market, however, has no impact on the size of the effort of product innovative firms. On the contrary, in the case of firms innovating only in processes our results show that the more concentrated the domestic market, the larger the innovation effort they display. As such, the incentives to innovate aiming at increasing market shares that one would expect to observe in a competitive setting are absent. A likely explanation is that the degree of risk aversion of relatively small agents operating locally is high. The result is also consistent with the estimated effect of firms' size on the intensity of innovation, larger for medium-large size units relative to that displayed by largest and smallest enterprises. This may be either due to them lacking incentives – given the firm itself having the greatest share of the domestic market – or due to them being already struggling to survive in such a non-competitive setting.

A last factor that significantly affects the innovation effort for firms innovating only in processes, while being non-significant in the case of firms that are product innovative, refers to the origin of the financial resources needed. As expected, the percentage of sales revenue invested in innovative activities will be larger whenever their financing does not stem solely from the firm's own resources.

Input-Output equations

The here estimated input-output equations reflect the size of the effort devoted to innovation activities has a positive effect on the relevance of the innovation output obtained, being the magnitude of the effect similar for both types of output. In order to increase the relevance of the innovation output in 10%, *ceteris paribus*, the size of the effort should be augmented in 40%. The result also depends on the innovative input on which increased resources are invested and is further different depending on the type innovation output.

The impact on the relevance of the innovation product obtained would be partially offset whenever the resulting diversification level is reduced, signalling at the existence of complementarities among innovation inputs, as measured by IICI2. In the case of innovation restricted only to processes, although the index itself is not significant, the model shows that if the increased effort is concentrated just in physical capital or training programmes, no positive impact on the innovation output relevance will be observed. The result is reflecting that the strategy most frequently pursued by process innovative firms is non-optimal regarding the chosen mix of inputs. As seen in the descriptive analysis, these units tend to concentrate their innovation expenditure more than product innovative units do, while the preferred inputs are K+H+S and Training, being the relevance of the output obtained lower.

Regarding the characteristics of the production factors included in the models, such as the labour force skill level, the existence of R&D formal units or the relative capital labour intensity, they are found to influence the relevance of the output obtained depending on the type of output. The degree of the novelty of processes appears to be associated to capital intensity, while that of products is linked to the skill composition of the firm's workers. A larger the scale of production promotes an increased relevance of the innovation output in both cases, although for firms innovating in products the effect is captured only for those in the largest size stratum.

Table 7 – Econometric Results

	Propensity	Innovation Effort		Innovation Output		Productiv Growth
Variables	**All firms**	**OnlyProcs**	**Product**	**OnlyProcs**	**Product**	**All firms**
ln Inn.Expenditure/Sales	---	---	---	0.26*	0.25***	---
ln K+H+S & TP/Sales	---	---	---	-0.23*	---	---
ln R&D & EID+TT+CS/ Sales	---	---	---	---	0.04	---
OIOI - All	---	---	---	---	---	0.02***
OIOI - Only Processes.	---	---	---	---	---	0.04***
Size: 20-49	0.13*	-0.12	-1.5***	0.07	0.26	---
Size: 50-149	0.27***	-0.76*	-1.6***	0.25*	0.23	---
Size: 150 & more	0.36***	-0.58	-2.1***	0.52***	0.57***	---
Size: 50 & more	---	---	---	---	---	-0.028
Engineers/Professionals firm	0.24***	0.69*	0.12	0.10	0.22**	---
Profs/Empl.– Dev.firm/sector	0.56*	-1.3	-2.9***	---	---	---
Formal R&D unit 1 lag	0.13*	-0.09	0.22	0.17	0.13*	---
Formal R&D in all three periods	---	---		0.32	---	---
% Foreign capital	-0.28**	-0.26	-0.10	0.11	0.16	---
Economic group_d	0.02	---	---	---	---	---
Full export	0.29	0.15	1.5***	---	---	---
Export&local market	0.08	---		---	---	---
Avg.labour productiv. 1 lag	0.06**	---	---	---	---	-0.36***
Machinery/L, 1 lag	---	-0.01	-0.03	-0.08*	0.05	---
Capital/Labour - Rate of Growth	---	---	---	---	---	0.14***
Labour - Rate of Growth	---	---	---	---	---	-0.0
K/L, 1 lag	0.00	---	---	---	---	---
Productive capacity - % use	0.11	0.52	-0.62	---	---	---
Expenditure in R&D - Dummy	---	-0.62**	-0.62***	---	---	---
Expenditure in K+H+S - Dummy	---	0.51	0.55**	---	---	---
Expenditure in TP - Dummy	---	-0.68**	0.72***	---	---	---
Expenditure in EID - Dummy	---	0.04	0.09	---	---	
IICI	---	-2.7***	-1.02***	---	-0.47***	---
Obstacles: firm	-0.13*	---	---	---	---	---
Obstacles: macro	-0.01	---	---	---	---	---
Obstacles: market	0.01	---	---	---	---	---
Financing - Own resources only	---	-0.55**	-0.26	0.24	-0.21	---
Financing - Related agents	---	---	---	0.40	-0.34	---
Financing - Public sector	---	---	---	0.29	0.07	---
Financing – Banks	---	---	---	0.42*	-0.20	---
Financing - International	---	---	---	1.4	-1.3***	---
Linked with NIS	---	---	---	0.18	-0.28**	0.02
Link for technical assistance	---	---	---	0.04	0.09	---
Link for R&D	---	---	---	0.18	0.08	---
Link for training	---	---	---	-0.05	0.18**	---
Link for information	---	---	---	-0.05	-0.10	---
Inform. Source: gral knowl.	-0.02	---	---	-0.28*	-0.09	---
Inform. Source: specif. knowl.	0.20 ***	---	---	0.02	-0.055	---
Inform. Source: consultants	-0.01	---	---	-0.01	-0.08	---
Inform. Source: headquarters	0.06	---	---	0.01	-0.06	---
Inform. Source: related agents	0.10	---	---	0.14	0.02	---
Inform. Source: internal	0.17***	---	---	-0.05	0.23***	---
Business cycle sector	1.2*	-1.1	-0.19	-2.7**	-2.3**	3.9***
Concentration market	-0.01	1.3***	0.16	0.33	-0.15	0.23***
Uncertainty	-2.9	---	---	---	---	---
Number of Observ.	1388	298	484	268	451	1221
PSUs/Strata	672/4	246/4	323/4	220/4	303/4	610
Rho	0.27	0.06	0.34	0.0581	0.0902	0
Over-identifying Restrictions	-----	-----	-----	3.00	11.817	-----

Notes: The first column reports results on marginal effects (dy/dx). "PSUs" states the number of cross-section units in the diverse "Strata" according to the survey design. P-probabilities are reported, */**/*** corresponding to rejection of H_0, the tests being of size 10%, 5% and 1%, respectively. All diagnostic tests performed indicate the models are well behaved.

Differences between the two types of output are also found with respect to the role of NIS agents and information on the degree of novelty attained. The ability of capitalizing internal information sources and the existence of links with the NIS agents in order to improve or access training programmes are positively affecting the firm's ability to obtain innovative products of higher relevance. None of these variables is significant for the extent or relevance of innovative processes, however. Contrariwise, for the latter subgroup of firms the use of information stemming from general rather from specific knowledge generating institutions – e.g. universities – seems to affect negatively the degree of novelty of the processes obtained. Firms having had established a link to the NIS seeking for collaboration in their R&D effort, or seeking for information or technical assistance did not significantly impact the enterprises' ability of generating a more relevant innovation output. The result may be pointing at a failure of the NIS in terms of the quality of the advice provided, but it may also be reflecting the fact that the firms that need to approach such actors are those with a lower capability of attaining a high relevance level output.

The stage of the business cycle is surprisingly not relevant for the intensity of innovation, but it does have an anticyclical impact on the ability of firms for transforming innovative inputs into output. As such, it reflects that Uruguayan firms not only focus on getting a high relevance innovative output when faced to adverse economic conditions, but that they do succeed more frequently in such circumstances.

Productivity growth

The impact that the innovative behaviour of firms has on the rate of labour productivity growth is captured by specifying a Cobb Douglas production technology, in which the index of relevance of innovation output enters as a third factor of production. We also include controls for the procyclicality of productivity growth; for the positive bias registered by exporting firms; for the effect of the previous level of the firm's productivity on the relative size of its rate of growth; and for the prevailing degree of concentration in the firm's sector. Individual effects associated to unobservable sector characteristics are also included, being them different – and positive - only for Petroleum and derivatives and for the Beverage industry. The production inputs included are the total stock of physical capital and total employment. The resulting technology exhibits constant returns to scale, being the returns to innovation non-negligible. The elasticity of physical capital is low – 0.13- further reinforcing the starring role of the skill level of the workforce as key for engaging in innovative activities.

The results reveal that the returns of innovation for Uruguayan firms are significantly positive and of a much larger size for process than for product innovation. Improving the relevance of the obtained innovation output when involving novel products by 10% would increase the rate of growth of productivity in 1.5% while if only process innovation is obtained, the effect rises to 2.4%. Consequently, they support our initial hypothesis that accounting for process innovation for a small, developing country like Uruguay is a key issue, since the positive effects of innovation on productivity growth mainly stems from process innovation and not from product innovation. Neglecting process innovation and disregarding the degree of relevance of the innovation output obtained are very likely reasons explaining why previous research for non-developed countries has found no significant effects of innovation on dynamics of productivity.

Conclusions

One possible underlying cause of Uruguay's meagre performance in terms of *per capita* growth rates is the observed insufficient effort devoted to borderline activities. We here found that process innovation, the most frequent type of output pursued, has a positive impact on production by accelerating labour productivity growth, the size of the effects when only novel process are obtained being substantially larger than when innovative products are also involved. The conclusion is further consistent with the observed increasing proportion of large firms switching from product to only processes innovation, especially when considering that they are are the core of innovative firms with respect to the international market. Thus, the results point at high relevance process innovation being crucial for improving the economic performance of Uruguayan manufacturing firms, and probably for those in other small developing countries as well. Further, the evidence points at technological aspects as the main cause of the scarce dynamics of innovation and their insufficient enhancing productivity effects. Firms displaying a dynamic and borderline innovative behaviour combine inputs in a diversified manner, being the investment in R&D and in Engineering & Industrial Design of a similar magnitude than that of training programmes and physical capital. They also tend to get both processes and product innovation, as opposed to those firms that focus just on processes by means of highly concentrating investment in the latter two mentioned inputs. A reliable cause is the lack of relevant information on the optimum technology for transforming innovation inputs into output, especially for small firms not taking full advantage of NIS assistance.

Given the above, policy action should be focused on generating and spreading relevant information on the relative effects of innovative activities of different nature and on how to attain the optimum input mix in order to obtain the needed type of innovation output. The generation and publication of this type of information may be done by existing public institutions devoted to research. 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. Since the most relevant innovation output to boost productivity appears to be the innovation in processes, Uruguayan firms are most likely operating below their optimum efficiency level, while they are not able to leverage their product innovation because of them having weak internal processes. This entails the recommendation for NIS agents of aiding local firms to improve their internal processes before pursuing other type of innovation activities. One could think of developing conditioned loans for firms, compelling firms to first adjust and improve their processes, before granting financial aid devoted to product innovation.

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