A Contribution to the Explanation of the Long-Term Path of Growth in Uruguay.

The Role of Risk Aversion, ICT, and Innovation.[1]

Ricardo Pascale [2]

ABSTRACT

During the last five decades, the Uruguayan economy has shown evidence of decline, particularly in terms of GDP per capita at PPP, relative to knowledge-based economy countries. This paper examines –in an attempt to try to contribute to a better understanding of this phenomenon-, three main points. These are: What are the determinants of innovation?; What are the links between innovation and TFP?; and, What variables explain the growth of firms in Uruguay? The use of ICT (in positive) and RISK (in negative) explain the determinants of innovation dynamism in Uruguay. RISK –a variable usually non-existent in models for developed countries-, is taken as a proxy of the risk aversion attitude of the entrepreneur and plays a severe negative influence on innovation. Process innovation has a positive effect on the explanation of the TFP, and the growth of firms is explained not only by labor or capital (human and physical), but also depends positively on the use of ICT, and negatively on RISK.

Key Words: Innovation / Risk Aversion / TFP / Growth

RESÚMEN

Durante las últimas cinco décadas, la economía uruguaya ha mostrado evidencias de declinación, especialmente en términos de PIB per cápita en PPC, en relación con los países de economías basadas en el conocimiento. En este trabajo se examinan -en un intento de tratar de contribuir a una mejor comprensión de este fenómeno-, tres puntos principales. Estos son: ¿Cuáles son los factores determinantes de la innovación?; ¿cuáles son los vínculos entre la innovación y la PTF, y, ¿qué variables explican el crecimiento de las empresas en Uruguay? El uso de las TIC (en positivo), y el RIESGO (en negativo), explican los determinantes de la dinámica de innovación en Uruguay. RIESGO, -una variable generalmente inexistente en los modelos de los países desarrollados-, es tomada como un proxy *de la actitud de aversión al riesgo del empresario y juega una influencia negativa sobre la innovación. La innovación en procesos tiene un efecto positivo en la explicación de la PTF, y el crecimiento de las empresas se explica no sólo por el trabajo o el capital (físico y humano), sino que también depende positivamente del uso de las TIC, y negativamente del RIESGO.*

Palabras Clave: Innovación / Aversión al Riesgo / PTF / Crecimiento

JEL Classification: O14 - O32

[1] This paper draws in grand extent on the doctoral thesis of Ricardo Pascale *"Economía del Conocimiento en países subdesarrollados: TIC, innovación y productividad. Un análisis de la industria manufacturera en el Uruguay", (2007)*.

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1. INTRODUCTION

1.1. Motivation

During the last five decades, the Uruguayan economy has shown evidence of decline in relative terms comparing with KBEs (Knowledge Based Economies).

This was the first motive. The economic life of Uruguay shows two main sub-periods. The first one, which covers until the mid 20th - Century, was a sub-period of growth.

The second period, from mid 20th - Century until the present, -in spite of swings in GDP (Gross domestic product) growth- is a sub-period with a trend of economic decadence in relative terms.

In these last fifty-six years, the GDP per capita measured in constant PPP (Pen World Table. Version 7.1, July, 2012)[3] was, in 1955, similar to or higher than that of Italy, Spain and France, while in 2010, it was less than a half than that of these countries.

In smaller countries the phenomenon shows a similar path. For example, in 1955 Uruguay and Finland had a similar GDP per capita; today the Uruguayan GDP per capita is approximately a third of that of Finland. Similarly, in 1955, Australia had a GDP per capita at Purchasing Power Parity slightly more than twice that of Uruguay. In 2010, the size of Australia's GDP per capita is four times that of Uruguay. Similar trajectories may be observed for Singapore, Taiwan and Korea. Many Latin American countries follow a similar pattern to that of Uruguay.

A second motive rests on the underlying causes of these large differences of long-term economic growth between countries. Furthermore, the majority of the research on economic growth is done in developed countries and not in less

[3] Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 7.1, Center for International Comparisons at the University of Pennsylvania (CICUP), July, 2012.

developed countries (LDC), where the needs for research on growth are much higher.

Finally, as a fourth motive to undertake this research, most of the studies regarding economic growth in LDC are based on secondary variables with high level of aggregation, and research based on primary and microeconomic variables is practically non-existent.

In this scenario, the following issue emerges dramatically: What happened in Uruguay to explain this sustainable downturn behavior? It is important to point out that this decline in innovative terms was more severe in the last thirty years, due to the emergence of the knowledge-based economy in many countries.

1.2. Purpose

The *purpose* of this research is to study, at a microeconomic level (firms), the determinants of innovation, and their importance in the productivity of the firms. The purpose covers the analysis of the role of the Information and Communication Technologies (ICTs) in process innovation and in the Total Factor Productivity (TFP), and of the main factors that explain the economic growth of firms in Uruguay[4].

1.3. Research Questions

This study explores three *research questions:*

a) What are the determinants of the innovation dynamism of firms?

b) What is the relationship between innovation and TFP growth?

c) What variables explain the economic growth of firms?

[4] The latest studies conducted by the National Agency of Innovation and Research (Agencia Nacional de Innovación e Investigación, ANII) record a constantly low innovation dynamism in Uruguay during the 2007-2009 period, in relation to that recorded in 2001-2004, which was the period covered by the research, with a focus on the Uruguayan manufacturing industry.

The approaches to cope with these questions will be developed in the rest of the study. Section 2 briefly reviews the different contributions to the theory of economic growth in relation to technological progress. Section 3 develops the methodology applied in the study. Section 4 describes the data collected. Section 5 sets out the econometric results. Section 6 concludes.

2. BRIEF REVIEW OF THE LITERATURE

The theory and empirical evidence related to technological progress and growth has been the subject of numerous and excellent studies. Therefore, in this opportunity, just a brief revision of some main points in connection with the objectives of this research will be covered.

2.1. Technological Progress and Economic Analysis

Classic authors such as Smith (1776), Ricardo (1817) and Marx (1867-1883) made significant contributions to the topic. In Marx, innovation and technological progress take an important role. From technical progress and innovation on physical capital, an increase of the surplus value for the individual capital is produced.

Schumpeter (1911) pointed out the role of the innovative entrepreneur and the "creative destruction", placing innovation as a key factor in order to explain economic growth. This orientation was later extended and renewed in 1934.

Solow (1956) achieved a remarkable advance when he formalized technological progress and knowledge on the growth models. In the Solow model, technological progress is exogenous. Nearly concomitantly, other contributions such as that of Hicks (1965) left aside some neoclassical hypothesis and pointed out the importance of surplus capital stocks on growth. The contribution of Salter (1960), on the role of physical capital on technological progress, and that of Schultz (1961) related to human capital, should be taken as a remarkable progress in the theory of growth.

Afterwards, on the endogenous models, the “learning by doing” of Arrow (1962), the propositions of Romer (1986, 1990), Grossman and Helpman (1991), and Aghion and Howitt (1991) are also significant. Lucas (1988) emphasized the importance of human capital; this can be considered as an extension of the Solow model with different levels of education.

On the contemporary vision of the economy of innovation, frequently influenced by evolutionism, opportunity and the technoeconomical paradigms, technological trajectories and networks appear, with the outstanding contributions of authors like Rosenberg (1976, 1982), von Hippel (1976, 1988), Nelson and Winter (1977, 1982), Pavitt (1979, 1984), Freeman (1982), Dosi et al (1982, 1988), Antonelli (1982, 1995, 1999), Pérez (2002), David (1990), and Lundvall (1988), among others.

For some authors, the most important factors that explain the differences of growth between countries, based on these current theories, do not give a satisfactory answer. Then, another approach was developed, the one of economic history that has two main avenues: an institutional one, with the contributions of North (1990) among others, and a culture-based one, with authors such as Lewis (1955).

The academic vision of the LDC in terms of innovation, growth and development indicates that the contemporary visions of the importance of the economics of innovation are shared, as well as the contributions of Schumpeter, Solow and other authors mentioned. Nevertheless, the convergence of productivities did not occur, and on the other hand, there exists a conviction that the ideas stated on the Washington Consensus are not sufficient to promote development in a world where the new knowledge-based economy is installed. Likewise, the studies on technology imitation and technology adoption are insufficient.

2.2. Digital Revolution

In this revision, it is crucial to report the appearance of the digital revolution, which took us to a new economy that is informational, global and networked, as Castells (1996) has stated. The ICTs are essential to promote knowledge, and this knowledge became the dominant factor to explain growth. Knowledge -like Stehr (2002) mentions- will be the raw material of this New Economy. A New Economy that, as Vilaseca and Torrent (2005) have pointed out, is characterized by the ICTs, for being global and also by the appearance of new types of demand.

The empirical evidence has validated the importance of the digital revolution on technical progress and productivity, as was demonstrated by Brynjolfsson and Hitt (1995), Brynjolfsson and Yang (1996), Bresnahan, Brynjolfsson and Hitt (1999), Brynjolfsson and Hitt (2003), Greeman, Horty and Mairesse (2002), Timmer, Ypma and van Ark (2003), and Jorgenson, Ho and Stiroh (2005).

3. METHOD

The research follows mainly the quantitative methodological vein. Nevertheless, a combination was made –at the level of techniques- of the quantitative and qualitative approaches.

The fundamental problems in the quali-quantitative debate remain at the ontological and epistemological level, which summarize two paradigms still not integrated (Guba, 1987). But, at the methodologically technical level it is possible and useful to combine techniques of both approaches.

The reasons to include this combination in this study were basically two:

a) The highly complex subject under study called for the need to have different perspectives to better analyze it, and

b) The scarcity or non-existence of previous studies that cover the topics under research.

The combination of both technical approaches -quantitative and qualitative- was very important to better understand the complex field under analysis.

In this way, it is possible to:

a) *Identify relevant variables,* such as the *severe risk aversion* of the Uruguayan entrepreneurship. This combination of techniques sought to explore in more detail the field under study which until the present received little attention, as well as to identify those phenomena usually not considered in developed countries, as the mentioned case of *risk aversion*.

b) *Improve the variable definitions and the measures* achieved.

c) *Secure data collection*, information crossing and to reduce non-sampling errors.

3.1. Qualitative Techniques

Two main qualitative techniques were used:

a) Discussion Groups and b) Semi-Structured Interviews.

Three Discussion Groups were formed in order to explore the relationship between the generation, circulation and appropriation of knowledge within the firms and their use in potential process innovation.

The sample was selected for the purposes of the study, and a severe quality control of the results was carried out: later, the results were codified and analyzed.

Eleven Semi-Structured interviews were made with the goal of capturing more specific and profound information on the innovation dynamism of the firms. The sample search for a better selection of the interactive context is relevant for the purposes of the study.

3.2. Quantitative Techniques – The Sample

A survey was conducted to collect information for model building.

Taking the population of 2593 manufacturing firms with more than five employees,[5] a representative sample of 252[6] of them was established. In most cases (159), the questionnaire was filled during a personal interview done by the researcher. A high degree of response was obtained (249 firms, which represent 98.8% of the sample).

The sampling planning was a stratified one. Two types of strata were considered. One stratum was by size (measured by the number of employees). Four sizes were determined (5-10, 20-99, 100-199 and more than 200 employees). The second stratum was determined by technological intensity, classified as low, medium and high technology, according to the approach established by Hatzichronoglou (1996) and Vilaseca and Torrent (2003).

The selection of samples was done in the following way: a) firms with more than 200 employees, census; b) other strata, with optimal size and random selection.

The global error of the sample was ± 1,36% with a 99% confidence level.

3.3. Definition

The definition of *innovation* adopted in this study is a wide one: that is, the *`successful exploitation of new ideas´.* Four features are important in this definition: the existence of a new idea, the knowledge, the use of these ideas and the creation of value achieved by the new ideas.

[5] According to the National Institute of Statistics and the National Chamber of Industries.
[6] Represents more than two thirds of the Industrial GDP.

Four dimensions of innovation were also explored: product innovation, process innovation, organization innovation and commercialization innovation.

In each dimension of innovation, the analysis focused on the scope of the variable to be explained, such as: innovation for the firm, for the country, for Mercosur and innovation for the world.

The other important definition used in the study refers to the TPF. In this research the TFP was obtained as a “residual”, using the standard Growth Accounting approach. The TFP was calculated for each firm included in the sample.

3.4. Models

In order to answer the research questions established at the beginning of this study, the models used for that purpose differ for each question, and they are summarized as follows.

Models for the Determinants of Innovation

The different dimensions of innovation are treated as a dichotomous variable. As a consequence, the econometric strategy was oriented towards the models with qualitative dependant variable.

Logistic regression, which is useful for categorical response data, was utilized for modeling the determinants of innovation according to Agresti (2003), Amemiya (1985), Gourieroux (2000), Maddala (2001), Cramer (2003), and Greene (2003).

Taking the case of a binary response variable Y and X as explanatory variable; the model of logistic regression, being $\pi(x) = P(Y=1 \mid X = x) = 1 - P(Y = 0 \mid X = x)$, is:

$$\pi(x) = \frac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)} \qquad [1]$$

The *logit,* (the log odds), can be represented by the linear relationship

Logit $\left[\pi(x)\right] = Ln\left[\frac{\pi(x)}{1 - \pi(x)}\right] = \alpha + \beta x$ [2]

The link function logit conducts to the linear predictor.

In this research, there are several potential explanatory variables of innovation.

Then $x = \left(x_{1,}, x_2, x_3, ...x_j\right)$ which corresponds to a *j* predictors,

Logit $\left[\pi(x)\right] = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_j x_j$

And the logistic regression model became:

$$\pi(x) = \frac{\exp\left(\alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_j x_j\right)}{1 + \exp\left(\alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_j x_j\right)} =$$

$$= \frac{1}{1 + \exp\left[-\left(\alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_j x_j\right)\right]} \qquad [3]$$

For each dimension of innovation a maximum likelihood estimation of the binary logit model was obtained. The goodness-of-fit was studied through the likelihood-ratio test statistics. The Wald statistic was obtained to analyze the variable significance. The Hosmer – Lemeshow Test was also used to estimate probability values, and the Cox-Snell R-squared and the Nagelkerke R-squared in each logistic regression model were obtained.

Model for the Links between Innovation and TFP.

The modeling of the relationship between innovation and PTF started with the Solow model (1956, 1957), and was extended to include not just labor and physical capital, but other variables such as innovation, ICT, or human capital.

The purpose of the research is not just to obtain the non-explained residual of the regression in the Growth Accounting approach, but also to try to determine, as much as possible, the explanatory variables of this residual.

In order to determine the relationship between innovation and TFP, the equation to be estimated takes the following form:

$$\Delta \ln TFP_i I = a\Delta(k-l)_i + bINNPROD_i + cINNPROC_I + dINNORG_i + \\ + eINNCOM_i + f\Delta yI + \sum g_{nj} TI_{ji} + \sum h_{sj} S_{ji} + \mu_i \qquad [4]$$

where:

$\Delta \ln TFP_i I$ = Rate of variation of the TFP (in log) of the firm *i* of the *I* sector.

$\Delta(k-l)_i$ = Rate of variation (in log) of quantity of capital per employee of the firm *i.*

$INNPROD_i$ = Product innovation as a dichotomous variable of firm *i.*

$INNPROC_I$ = Process innovation as a dichotomous variable of firm *i.*

$INNORG_i$ = Organization innovation as a dichotomous variable of firm *i.*

INNCOMi = Commercialization innovation as a dichotomous variable of firm *i.*

Δ *y I* = Rate of variation of the output of the *I* sector of the firm

TI_{ji} = Technological intensity as a categorical nominal variable of the firm *i* of the *j* technology level.

S_{ji} = Size as a categorical ordinal variable of the firm *i* of the *j* size.

μ_i = Random error term for firm *i.*

The significance of the model was tested through the F statistic following with the P>F and was done with a significance level of 5%.

The significance of the parameters was tested with the *t* statistic. Also robust standard errors were calculated.

Model of the Growth of the Firm.

The model for growth of the firms was developed using the different data and results from the two previous modelizations, (the determinants of the innovation dynamism and the link between TFP and innovation). The formal model is presented in section 5.

The model obtained draws from two streams of literature. The first evolves in the framework of growth accounting that follows the contributions of Solow (1956, 1957) about the importance of technological change to economic growth. Also, the model has benefited from other stream of literature, in the vein of the Neo-Schumpeterean tradition, with the works of Dosi *et al* (1988), Silverberg and Soete (1994), Stoneman (1995), Freeman and Soete (1997), more involved in an out-of-equilibrium approach, using different methodologies and indicators.

4. DATA SET AND VARIABLES

The econometric estimation of the model presented in Section 5 (for the determinants of innovation as well as for the link between innovation and TFP), was carried out using a new and original firm-level data set built with the information collected during the survey.

The data was obtained from a questionnaire that was first tested in a group of firms, and the final version takes many of the insights emerging from this preliminary version.

The one hundred and eleven questions –final version- of the questionnaire were completed by the firms included in the sample. The concerns of the entrepreneurs about the discretion in the use of the data supplied, and the need to improve the quality of the data collected was the reason why the researcher decided on personal interviews with them.

The questionnaire completed was carefully analyzed, to ensure the accuracy of the data collected.

4.1. On Data and Variables for the Determinants of Innovation

The Dependent Variable: Innovation

Innovation, the variable to be explained, typically shows in the empirical evidence three main ways to be measured. The first one through *inputs*, such as variables related to R&D. The second one through an intermediate product, the *patents*. And the third one through the *final innovation product.*

In the case of Uruguay, the last one was adopted as a measure of innovation, in the four dimensions studied for the variable (product, process, organization and commercialization innovation). And each one assumes the type or dichotomous variable.

The other two possibilities have been discarded. The input R&D-related variables became, in the case of Uruguay, practically not applicable. The same happened for the case of patents.

The Potential Explanatory Variables

A wide spectrum of potentially explanatory variables of innovation was taken into consideration in this study. They come –in this research- from two main sources:

a) The extended theoretical literature and empirical studies, related to the determinants of innovation in several countries, and

b) The insights provided by the qualitative research techniques used. The most remarkable case was the severe risk aversion of the Uruguayan entrepreneur, designed as the RISK variable.

The significance analysis was applied to the set of variables primarily included in this study. In the case of categorical variables, contingency tables using Pearson chi-squared were applied. In the case of continuous variables, logistic regression was used.

The following table shows those variables that were significant at 5% level and were used for the econometric estimation of the determinants of innovation.

Table 1 - Potential Explanatory Variables used in Econometric Estimates of the Determinant of Innovation

Acronym	Proxy	Type
PROP	Majority proprietorship of domestic investors	Dichotomous
EXP	% of total sales assigned to exports	Continuous
RISK	Absolute Risk Aversion of entrepreneurs	Continuous
ENTREP.	Number of new projects started (2001-2004)	Continuous
PUBPOL	Public Policies concerned with innovation	Dichotomous
KNOWL	Existence knowledge management with policies	Dichotomous
R&D	% of sales assigned to R&D	Continuous
ICT	Weighted Index of ICT used in : R&D, e-learning e-commerce, accounting, administrative affairs	Continuous
SIZE	Size of firms (S1, 5-19; S2 20-99; S3, 100-199; S4, more than 200 employees)	Categorical Ordinal
TECHIN	Strata of technological intensity	Categorical Nominal
RPAT	Number of registered patents (2001-2004)	Continuous
R&D FIN	Financing of R&D with equity	Dichotomous
R&D FINE	Amount of R&D financed with equity	Continuous

Source: Pascale, (2007).

The foregoing variables were used for the econometric estimation of the determinants of innovation.

4.2. The RISK Variable: A Closer View

The RISK variable is usually not included in the theoretical and empirical studies on innovation and growth in highly developed countries. In those countries, the RISK variable, in relation to the entrepreneurs, goes through a "normal" path. This is not the case for Uruguay, where the entrepreneurs show a severe risk aversion pattern on the decision-making process. This variable was highlighted in the qualitative approach used in the methodological strategy.

The RISK variable in this study has its first roots on the work of Daniel Bernoulli (1738), who developed the concept of expected utility, displacing the previous paradigm of monetary expected value. Bernoulli introduces the subjective preferences about risk. More than two hundred years later, in 1944, John Von Neumann and Oskar Morgenstern took his ideas in a formalized expected utility function. This normative theory shows that it can be calculated as a number that represents the expected utility of the decision. The expected utility function is built making questions about uncertainty situations. The answers to these questions represent the points of the utility function.

The expected utility theory rests on a maximizing, omniscient man. In other words, it rests on the *Homo Economicus.*

Simon (1947, 1957, 1969, 1971, 1978, 1991) and Allais (1952) made severe criticisms to this kind of complete rationality, and the first one coined the term *bounded rationality.* Different authors (Thaler, Camerer) found anomalies in the expected utility theory.

A new approach with high cognitive emphasis, found in the Prospect Theory by Tversky and Kahneman (1979, 1992), made a major breakthrough. This descriptive theory of decision-making introduced powerful cognitive insights enriching the expected utility theory in the explanation of decision-making in the real world. This new approach seems to rest on the *Homo Sapiens* (Thaler, 2000)

In this research, the RISK variable was measured through the Absolute Risk Aversion (ARA), by Arrow (1965) and Pratt (1964) for each entrepreneur. Nevertheless, the cognitive insights of Tversky and Kahneman were important in cases of notorious anomalies.

For each entrepreneur the Absolute Risk Aversion was defined as:

$$\text{ARA} = ap(w)_{ij}^{k} = \frac{-\mu''(w)_{ij}^{k}}{\mu'(w)_{ij}^{k}} \qquad [5]$$

Where:

$\mu(w)_{ij}^{k}$ is the utility function of the *k* firm, of the size *I* and technological intensity *j.*

The technique used was to fit the answer vector through least squared to the potential function.

$$\mu(w) = \alpha + \beta w^{\gamma} \qquad [6]$$

With this approach, it was possible to build individual expected utility functions, and then to capture the errors in the answers and gain the possibility to make inferences.

During the interviews, 97% of the entrepreneurs declared themselves as highly risk averters, the 2% neutral to risk, and 1% as risk seekers. Related to the causes of these attitudes, in 81% of the cases, the entrepreneurs mentioned three main factors: a) instability of the macroeconomic policies; b) non-existence of economic growth policies and c) the memory and entrepreneurial habits related to protectionist governments. This was particularly emphasized during the import substitution period.

4.3. On Data and Variables for the Analysis of the Link between Innovation and TFP

The data for the econometric estimation of the model illustrated in section 3 for the link between innovation and TFP was obtained by means of the survey already mentioned.

The quantitative variables obtained were used in constant terms, using for these purposes the sectoral price indexes compiled by the Central Bank of Uruguay (BCU) to deflate the National Accounts figures.

In this research, the value added by the firms was calculated as a percentage (supplied by BCU) of the total gross output of each firm (sales value less inventory variation). The sales values used were included at producer prices (no value added tax was included, neither other sales specific taxes).

The raw material price data supplied in the questionnaire include indirect taxes paid (excluded VAT). In the case of exporters, the firms receive a tax rebate, and therefore the price paid for the raw materials reported in the survey was higher than the effective cost for exporters. This situation was adjusted by adding the tax rebate to the value added previously calculated for the exporting firms. This was also, the procedure used by Jorgenson, Ho and Stiroh (2005).

To calculate the TFP, the GDP variable or value added of the firm was chosen. In other works, (Jorgenson *et al*, 2005), the total gross production was used, which includes the intermediate inputs. In their study they considered it was important to evaluate the effects of some intermediary inputs (such as semiconductors) on the global productivity of the economy, otherwise its incidence is not detectable using GDP as a variable.

The reason why GDP was used in this study instead of the total gross production value is that the innovation is concretized through an intermediary input. Furthermore, in Jorgenson *et al* (2005) study, they measured this variable because they work with the scope of the national aggregate level. The present study focuses on the firm level instead.

Another reason for the choice of the GDP in this study is that the importance of the activities that produce input products for the information industry is very low. Furthermore, in Uruguay there are no statistics for gross production at the sector level on a regular basis.

For these reasons the GDP of the firm was the variable used in this study.

In the process of analysis of results, a distinction was made between firms that mainly export their production and have domestic inputs, and those that are non-exporters with import inputs.

5. RESULTS

The models discussed in Section 3 have been empirically estimated using the data set and variables described in Section 4. Various specifications for each equation have been tested, using different sets of explanatory variables.

This section discusses the results of the empirically estimated models, respectively: a) the determinants of innovation; b) the link between innovation and TFP; c) a model of the growth of the manufacturing firms in Uruguay.

5.1. The Determinants of Innovation

Table 2 summarizes some of the main characteristics of Uruguayan manufacturing firms. The column "Traditional Industrial Uruguay" shows the results of the survey discussed in section 3. The other column represents the results of another group of 44 industrial firms that have received the subsidy for innovative project from the PDT (Program for Technological Development).

Table 2 – Descriptive Statistics – All the Firms –Main Characterization of Firms

Concept	Uruguay Industrial (Traditional)	Uruguay Industrial (Future)
1. Indicator of use of ICT (mean)	5,21	6,48
2. Innovation (percentage of innovative firms in Products / Processes)	33/34	70/70
3. Professionals in R&D on the total of employees (percentage)	4	72
4. Number of years from the foundation of the firm (less than 15 years on the total of firms, percentage)	8	91
5. National propietorship of firms (percentage on total of firms)	85,6	100
6. Gender of Executives (percentage on total of employees)		
Masculine	97	80
Feminine	3	20
7. Age of the direct employees of more than 55 years	61	10
8. Risk Aversion (percentage of total of firms)		
Averse	97	68
Neutral	2	24
Seeker	1	6
9. Vinculation with Universities for support in innovation (percentage of total of firms)	3	62

Source: Pascale, (2007).

There is a dramatic difference. The traditional firms (which are the majority) show very low innovation dynamism until now, (ANII, 2004-2006, 2007-2009)[7]; they also show the presence of stylized characteristics according to the old paradigm (Pérez, 1996)

Before presenting the econometric estimations, the different potential explanatory variables were analyzed and the possible association between them was tested.

For two continuous variables the Pearson correlation coefficient was used (or in case of great skewness, the Spearman test by ranges).

[7] These figures are very similar to those obtained by DICYT (Direction of Innovation, Science and Technology) in its 1998-2000 and 2001-2003 Surveys on Innovation. And obtained by ANII (National Agency of Innovation and Research) in its 2004-2006 and 2007-2009 Surveys on Innovation Activities in the Uruguayan Industry.

In the case of categorical variables, the Pearson chi-squared test was utilized, and in those cases in which one variable was categorical and the other continuous, the work was done with the Mann and Whitney Test.

The findings report a strong association between three variables, which are: ICT, KNOW, and R&D. For this reason, they were treated independently in the different estimations.

Table 3 reports the results of the determinants for *product innovation.*[8] This dependent variable was captured as a dichotomous variable.

Table 3 - Product Innovation – Estimation of the Explanatory Model - Uruguay – 2004 (Method of analysis: maximum likelihood estimation of the logistic regression; dependent variable: product innovation, captured as a dichotomous variable)

Explanatory Variable	B	Wald	Exp (B)	R
ICT	0,755 *** (0.157)	22.974	2.127	0.253
RISK	-3.213 *** (0.898)	12.794	0.040	-0.182
CONST.	-2.377 -1.142	4.331		

N = 246, Cox-Snell R^2 = 0.392, Nagelkerke R^2 = 0.533, Hosmer and Lemeshow Test= 0.133

Significant levels: *** 1%, ** 5%, * 10%.

Robust standard errors are shown in parentheses.

Source: Pascale, (2007).

Table 4 presents the classification table of this estimation.

[8] Working with one equation regression, the explanatory variables are taken as independent of the explained variable, at least simultaneously, which is particularly clear in the case of Uruguay.

Table 4 - Classification Table – Product Innovation

	PREDICTED		
OBSERVED	No	Yes	% Correct
No	136	16	89.47
Yes	25	69	73.40
Cut Value: 0,5		Overall	83.33

Source: Pascale, (2007).

Table 5 shows that two variables explain the product innovation: ICT (in positive terms) and RISK (in negative terms). Table 6 shows an important percentage of correct classification (overall as well as innovators).

Table 5 and Table 6 report the estimations of the model for *process innovation* and its classification table.

Table 5 - Process Innovation – Estimation of the Explanatory Model - Uruguay – 2004 (Method of analysis: maximum likelihood estimation of the logistic regression; dependent variable: process innovation, captured as a dichotomous variable).

Explanatory Variable	B	Wald	Exp (B)	R
RISK	-2,334 *** (0.529)	19.407	0.097	-0.233
ICT	1.076*** (0.206)	27.160	2.932	0.279
CONST.	-1.737 -1.583	1.204	0.176	

N = 246, Cox-Snell R^2 = 0.489 , Nagelkerke R^2 = 0.668, Hosmer and Lemeshow Test = 0.328

Significant levels: *** 1%, ** 5%, * 10%.

Robust standard errors are shown in parentheses.

Source: Pascale (2007).

Table 6 - Classification Table – Process Innovation

	PREDICTED		
OBSERVED	No	Yes	% Correct
No	143	13	91.70
Yes	24	66	73.30
Cut Value: 0,5		Overall	85.00

Source: Pascale, (2007).

Similarly to product innovation, in the case of process innovation the explanatory variables were RISK (in negative terms) and ICT (in positive terms). The classification tables also show a high level of correct classification (overall as well as innovators).

It is also useful to point out the scope of the product and process innovation, the results of which are presented in Table 8.

Table 7 – Descriptive Statistics – All the Firms – Scope of Innovation (% of all the firms)

		For the Firm	For the Country	For MERCOSUR	For Latin America	For the Rest of the World
Product Innovator Firms	33	96	59,7	14,6	9,7	7,3
Process Innovator Firms	34	95,2	41,1	5,8	5,8	--

Source: Pascale (2007)

Most of the innovation scope refers to the firm itself (96% in products and 95.2% in process). For Latin America, the figures drop sharply (9.7% and 5.8%, respectively). For the rest of the world, 7.3% of the firms developed this product innovation scope, and there is no innovation for the world in the case of processes.

In many LDC, and the case of Uruguay is an example, there is a low innovator dynamism. Actually, what exist are *imitation* as well as *technology adoption* through equipment acquisitions.

Questions arise such as: Is the entrepreneur who copies a product and introduces it in a country really an innovator? Is he an imitator or an innovator? It is clear that there is a situation of imitation of product or process. The evidence shows, nevertheless, that this process of imitation frequently involves product and process innovation (that could be valued).

In the estimation of the logistic regression for the results in the cases of organization and commercialization, the two significant explanatory variables were: RISK (in negative terms) and KNOW (in positive terms). The classification table shows an overall correct classification of 78.37% in the case of organization innovation and 84.08% in commercialization innovation. Conversely, the results of the correct prediction for innovators were weak, 17.54% and 39.22% respectively.

To sum up, the results of the econometric estimation of the determinants of innovation reports:

a) RISK is the unique variable that explains (in negative) the innovation in the four dimensions analyzed.

That is one of the main findings of the RISK variable, namely the extreme risk aversion of the Uruguayan entrepreneurs. This risk aversion has a negative influence on the innovation dynamism of Uruguayan firms.

b) The ICT represents knowledge and has a positive influence on innovation.

c) RISK and ICT explain product and process innovation with an important percentage of overall classification and innovator classification results.

d) RISK and KNOW explain organization and commercialization innovation, but with weak correct classification results in innovators.

These results contribute to the understanding of the very low dynamism of innovation, which is dominated by a severe entrepreneurial risk aversion.

5.2. The Relationship between Innovation and TFP

The estimation of the rate of variation of TFP was made through the Growth Accounting approach, assuming a Cobb-Douglas production function with constant returns. This approach allows breaking the results down into labor and capital factor as well as TFP.

Following this methodology the variation of TFP in the period 2001-2004 was calculated for each firm of the sample. The TFP was assimilated as the non-explained residual by capital and labor.

Table 8 shows the descriptive statistics of the rate of variation of the total factor productivity of the firms in the sample.

Table 8 - Descriptive Statistics of the Rate of Variation of the TFP (Δtfp).

All the firms - Uruguay 2001-2004 (in natural log)

Mean	0,009
Standard Deviation	0,041
Median	-0,001
Kurtosis	4,138
Skewness	-0,57

Source: Pascale (2007)

During the established period, the rate of exchange of TFP was close to 1%, with a wide variability.

The econometric estimation of the explanation of the rate of variation of TFP (Δln TFP) was made with the variables illustrated in equation [4] of Section

3. In other words, this model –the original model in this study – was made endogenous to the economy through the incidence of innovation, the possible existence of growing returns, the sectoral growth and the size and technological intensity.

Table 9 sets out the main results.

Table 9 - Robust Estimation of the Explanatory Model of the Rate of Variation of the TFP (Δtfp). All the Firms – Uruguay 2001-2004 (Method of analysis: ordinary least squared; dependent variable: variation of the TFP, captured as Δln TFP).

	Original Model	**RRE Included**
Explanatory Variables	*Coefficient*	*Coefficient*
Δ (k-1)	-0,194***	-0,199***
	(0,037)	(0,037)
INNPROC	0,342***	0,319***
	(0,044)	(0,048)
Δy	0,290**	0,227*
	(0,118)	(0,125)
RRE		0,231***
		(0,056)
S2	-0,136***	
	(0,050)	
S3	-0,132**	
	(0,057)	
Constant	-0,136***	-0,287***
	(0,041)	(0,090)
	N=148	N=148
	F (5,147) = 25,078	F (4,143) =31,564
	Prob > F = 0,0000	Prob > F = 0,0000
	Adjusted R2 = 0,469	Adjusted R2 = 0,568

Significant levels: *** 1%, ** 5%, * 10%.
Robust standard errors are shown in parentheses.

Source: Pascale, (2007)

The results presented in the original model column show that INNPROC (process innovation) is a significant positive explanatory variable of the rate of variation of TFP. Also the sectoral variation is a significant positive explanatory variable. The variation of capital per worker was –in the period- a significant negative explanatory variable. The behavior of this variable is probably due to the lagged consequences of the important 2002 Uruguayan financial crisis.

Out of these economic fundamentals explaining this rate of variation of the TFP, the changes in relative prices can distort the results. Sharp changes in relative prices are quite frequent in LDC. In the 2001-2004 period, the Uruguayan currency dropped 28% in real terms.

In the second column, the variable RRE (Real Rate of Exchange) was included to illustrate, not the economic substance of the explanation of ΔlnTFP, but the effects of the changes in relative prices in the results. The variable was a dichotomous one, taking the value 1 in the case of the exporting firms with domestic inputs, and value 0 in the case of non-exporting firms with imported inputs.

In this case the INNPROC remains explaining the rate of variation of the TFP, as well as Δ (k-l) and Δy.

It is important to highlight the strong association between INNPROC and ICTs, which suggests that ICTs are included in the explanation of the rate of variation of TFP.

RRE (and the adjusted R-squared growth) also appears as explanatory variable. Nevertheless, it is important to remember that this is due to changes in relative prices and not due to the economic fundamentals of the explanation of the phenomena. In other words, this effect is produced by the lack of capacity to properly measure the output under these circumstances. This type of errors is quite common in the estimation of TFP in LDC that suffer severe changes in relative prices, and therefore, for this reason it is important to avoid them.

To sum up, the results of econometric estimation of the explanation of the variation of TFP reports:

a) Process Innovation (INNPROC) has a positive effect on the explanation of the rate of variation of TFP.

b) There is an important positive association between INNPROC and ICT, as shown in the foregoing study of the determinants of innovation. Therefore, ICT positively influenced the rate of variation of TFP.

c) The rate of change of the sectoral output (Δy) is a significant positive explanatory variable of ΔlnTFP.

d) The rate of variation of capital per worker –in the analyzed period- also explains (negatively) ΔlnTFP in the analyzed period. The interpretation of the sign of the variable seems to be the lagged effects of the 2002 financial crisis with severe consequences on real economic activity.

5.3. A Model of the Growth of Firms in Uruguay

After obtaining the findings related to the determinants of innovation and those related to the relationship between innovation and TFP, some natural questions arise: What are the factors that explain the growth of firms in Uruguay? Is it explained just by capital and labor, or are there other factors that make TFP be different to zero? What is the role of ICT and RISK in this explanation? The Process Innovation (INNPROC) is the dimension of innovation that explains the rate of change in TFP. It was found that the INNPROC was determined by ICT and RISK. It is significant to analyze the relationship between the rate of variation of TFP, and the variables that explain the INNPROC, which are ICT and RISK.

To analyze this relationship the formalized model was:

$$\Delta tfp_i = a\Delta(k-l)_i + bICT_i + cRISK_i + dRRE_i + \sum njTI_{ji} + \sum_{sj} S_{ji} + \mu_i \qquad [7]$$

where:

$\Delta \ln TFP_i I$ = Rate of variation of the TFP (in log) of the firm *i* of the *I* sector.

$\Delta(k-l)_i$ = Rate of variation (in log) of the quantity of capital per employee of the firm *i.*

ICT = Weighted Index of ICT use: R&D, e-learning, e-commerce, accounting, administrative affairs of the firm *i*.

$RISK_i$ = Absolute Risk Aversion of the entrepreneurs of the firm *i*.

RRE = Real Rate of Exchange of firm *i.*

TI_{ji} = Technological intensity as a categorical nominal variable of the firm *i* of the *j* technology level.

S_{ji} = Size as a categorical ordinal variable of the firm *i* of the *j* size.

μ_i = Random error term for firm *i*.

Table 10, shows the results of the estimation of the model.

Table 10 - Robust Estimation of the Explanatory Model of the Rate of Variation of the TFP (Δtfp). All the Firms – Uruguay 2001-2004 (Method of analysis: ordinary least squared; dependent variable: variation of the TFP, captured as Δln TFP)

	All the Firms	**High Technology Firms**
Explanatory Variables	*Coefficient*	*Coefficient*
Δ (k-1)	-0,278*** (0,035)	-0,157*** (0,081)
RRE	0,161*** (0,056	
RISK	-0,334*** (0,054)	-0,457*** (0,126)
ICT		0,285** (0,134)
Constant	0,008 (0,051)	-0,009 (0,132)
	N=148 F (3,144) = 48,809 Prob>F = 0,0000 Adjusted R^2 = 0,675	N=34 F (3,30) = 10,081 Prob > F = 0,0000 Adjusted R^2 = 0,714

Significant levels: *** 1%, ** 5%, * 10%.
Robust standard errors are shown in parentheses.

Source: Pascale, (2007).

The first column of coefficients shows the results of the estimation for all the firms. The model was significant, as well as the explanatory variables that resulted from it: RISK and rate of variation of capital per worker and RRE. ICT did not appear as an explanatory variable for all the firms. This is a consequence of the scarce utilization of ICT in the strata of medium and low technology-intensive levels of firms.

The results of the model for the high-technology intensive firms appear in the last column of Table 10. The explanatory variables in this case are: ICT, RISK and Δ(k-l).

The results obtained imply that the total output variation of the firms is not just explained by the variation of capital and labor. There are other factors that make the TFP different to zero, and those factors are RISK and ICT. For the long-term consideration –with the available information –the model obtained must not contain short-term (circumstantial) variables, but rather those related to the structural and functional aspects of firms. In this case the model is:

$$Y = A(ICT, RISK)K^{\alpha}L^{(1-\alpha)} \qquad [8]$$

This means that the variation of the product (Y) not only depends on labor (L) or human and physical capital (K), but also on other variables. It also positively depends on the use of ICT, and negatively on RISK, a proxy of the risk aversion of the entrepreneurs. The RISK variable has a significant weight on the results of the function, and therefore, on the results of growth. This negative effect cannot be –for the time being- compensated by the use of ICT.

With a long-range vision, the instabilities of the economy remain included in RISK. RISK has a negative contribution to the growth of the firm, and on the contrary ICT, which represents knowledge, has a positive contribution to the growth of the firms.

To sum up, in a long-range model, TFP can contribute to explain the growth of the firms through the ICT and RISK variables.

6. CONCLUSIONS

In this paper, new and original firm-level data and specific models were used to investigate and attempt to answer the three research questions previously established (the determinants of innovation, the link between innovation and TFP, and explanatory variables of growth of the firms in Uruguay). Shedding light on these issues is of great importance not only to contribute to the understanding –at least to some extent- of the economic decadence of Uruguay in the last five decades, but also for policy purposes.

The main conclusions –presented for each question-, are the following.

In relation to the determinants of innovation of firms, they are:

a) Uruguay shows a weak innovative dynamism, particularly based on imitation and technology adoption through new equipment acquisition.

b) Two variables explain the innovation dynamism: RISK and ICT.

c) ICT, which represents a proxy of the use of Information and Communication Technologies to improve knowledge and innovate, positively affects the innovation dynamism in process and product innovation. In organization and commercialization innovation, KNOW, a variable with close associations with ICT, explains the positive forces to innovate.

d) RISK, which represents a proxy of the severe risk aversion of entrepreneurs, has a negative influence on the innovation dynamism of Uruguayan firms. This variable is practically non-existent in models built for developed countries where risk follows a “normal” path.

Also, RISK was the single explanatory variable that remained in the four dimensions of innovation.

Different theories can be applied to explain this severe attitude of the entrepreneurs, among others: economic history, with the importance of the institutional and cultural variables; time inconsistency of the decision-making process of governments and firms; the rest seeking theory with the implications carried from the import substitution model; the theory of non-cooperative equilibrium, summarized in the Nash equilibria, and the theory of agency with the agency problems between principal and agent. It is probable that all of these theories can contribute to a better understanding of the pattern of the RISK variable, and should be a topic in the agenda of future research. But, what seems to be clear is the harmful contribution that the applied policies have left in terms of severe risk aversion. On the other hand, a latent moral hazard seems to remain in the economic agents of the most varied sectors of economic life.

In relation to the links between innovation and TFP, the conclusions are:

a) Process innovation has a positive effect on the explanation of ΔlnTFP. The other dimensions of innovation - with the available data - did not appear as explanatory variables.

b) Due to the positive association between INNPROC and ICT, this last one seems to have a positive influence on the growth of TFP.

c) The sectoral growth also positively affects ΔlnTFP and, in the analyzed period, the capital per worker negatively affects ΔlnTFP.

The third research question relates to the explanatory variables associated to the economic growth of firms, and the conclusions are:

a) With the information available, a long-term model was obtained for this question: This model is:

$$Y = A\,(ICT, RISK)\,K^{\alpha}\,L^{(1-\alpha)} \qquad [9]$$

b) The variation of the product of the firm (Y) not only depends on L or K (human and physical capital), it also depends positively on the use of ICT, and negatively, on RISK. The negative effect of RISK has a severe weight in the results of the function, and seems not to be compensated by ICT.

c) A non-explained, specific residual still remains, and seems to rest on institutional considerations. Further research is needed to better understand this specific return.

The policy implications of these findings are crucial for economic growth. They are related to the challenge of diminishing the RISK variable to reduce the remaining non-explained specific residuals. They are also related to public policies on innovation, which in the preliminary findings seem to have a positive effect; nevertheless, the final answer to this issue still remains open.

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