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► **To cite this version:**

Mohamed Ayadi, Mohieddine Rahmouni, Murat Yildizoglu. Determinants of the Innovation Propensity in Tunisia: the Central Role of External Knowledge Sources. 2009. halshs-00368560

**HAL Id: halshs-00368560**

**<https://shs.hal.science/halshs-00368560>**

Preprint submitted on 16 Mar 2009

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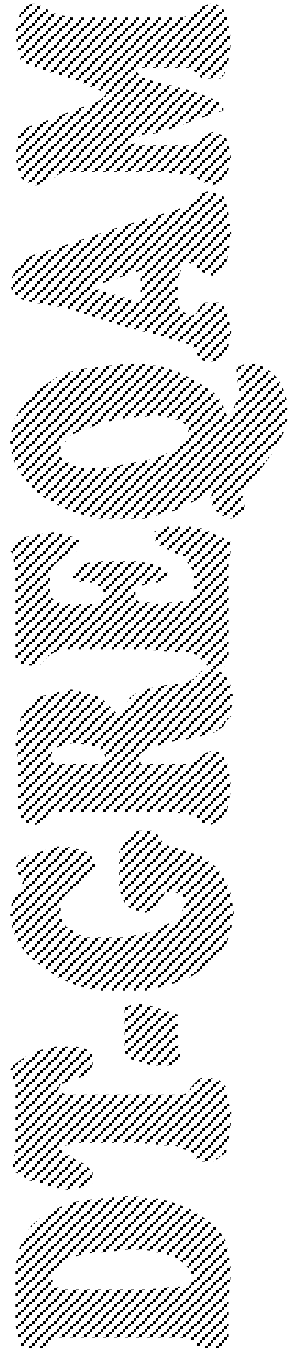
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Universités d'Aix-Marseille II et III**

**Document de Travail  
n°2009-05**

## **Determinants of the Innovation Propensity in Tunisia: the Central Role of External Knowledge Sources**

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**Février 2009**



# Determinants of the Innovation Propensity in Tunisia: the Central Role of External Knowledge Sources

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January 30, 2009

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## **Abstract**

This article is dedicated to the analysis of the first innovation survey of the Tunisian firms. Starting from basic mechanisms of innovation processes, we test a set of conjectures adapted to a developing country like Tunisia. We analyze the motivation of firms to innovate and the determinants of product and process innovations. Our results show that firms must benefit from external knowledge sources in order to exhibit significant innovation propensities. The large size is also a necessary (but not sufficient) condition for innovation. We also notice that the participation of the State plays an harmful role.

**Keywords:** Innovation, development, absorptive capacity, learning

**JEL codes:** O120; O300

# 1 Introduction

This study aims to analyze the main determinants of the innovative activity of manufacturing firms in Tunisia. We tackle this question through a systematic analysis of the first innovation survey carried out in this country in 2005 by the Ministry of Scientific Research, Technology and Competency Development (MSRTCD)<sup>1</sup>. This analysis allows us to test, in the context of a developing country like Tunisia, the basic results of a very rich literature on innovation, mainly focused on industrial countries. This literature emphasizes the importance of a large set of factors in the determination of firms' innovation behavior. However, controversial viewpoints are discernible within these studies and they do not always provide clear-cut results. Since the 1980s, contributions to this research area recognize that the determinants of innovation are subject to a number of moderating conditions such as the demand, the firm size, the absorptive capacity of firms, the industrial sector and the national environment (Souitaris (2002)).

The aim of this article is to analyze the main determinants of the propensity to innovate of Tunisian firms<sup>2</sup>. Given the shortcomings of the dataset (discussed below, in section 3), we focus our analysis on a small set of basic mechanisms that systematically appear in the literature on innovation: the role of demand, firm size, internal R&D of firms and external sources of technological knowledge. We adapt the qualification of these mechanisms to the context of a developing country and complete them by including the role of exportations and participation of the state to the capital of firms<sup>3</sup>. We develop an econometric model based on these basic mechanisms and estimate, using regression trees and discrete choice models, the effects of these factors on the ability of firms to innovate. This study is one of the first articles that propose a systematic analysis of the innovation processes in Tunisia.

The context of a developing country implies two important modulations of the concepts and results developed for industrial countries. First, we can expect a balance between the determinants of innovation quite different from the one observed in the innovation studies that are based on formal R&D investments of firms (*see* also Bell & Pavitt (1993)). Second, we observe that in developing economies all firms can not necessarily develop completely new and better products or production processes for the market. Many innovations simply consist in introducing better products that are new only for the Tunisian firms, without being new at the international level. Thus, our analysis is not restricted to the group of firms that undertake formal R&D activities, but it covers all firms that rely on the introduction of novelty to face the market competition and demand. This more broad definition of innovations is also adopted by other studies on developing countries (*see* for example Almeida & Fernandes (2007) or Kannebley, Porto & Pazeollo (2005)).

The following section discusses the main determinants of innovation that have been emphasized in the theoretical and empirical studies. This discussion allows us to formulate a set of conjectures on the determinants of innovation in a developing country like Tunisia. The third section presents the dataset that we use, as well as the research methodology that we adopt to analyze it. The fourth section is dedicated to our results. We first proceed with a quick analysis of the declared motivations of firms for their R&D activity. The results indicate that product and process innovations do not respond to the same objectives and they should be studied separately. We then present the results of the probit models. These models are formulated in accordance with the conjectures proposed in the second section. The interaction between the determinants of the propensity to innovate is further analyzed using regression trees. The last section concludes the article. Detailed statistical results are provided in the Appendix at the end of the article and in a complementary appendix available on-line.

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<sup>1</sup>This survey is based on the well known CIS methodology. The authors are very grateful to Hatem Mhenni, National Observatory of Science and Technology, for providing the data.

<sup>2</sup>The dataset we use do not contain any information on the intensity of innovation (the number of innovations), but just on the success or failure of the firms in product and process innovations during the three years preceding the survey.

<sup>3</sup>For a in depth comparison of technological development processes in developed and developing countries *see* Bell & Pavitt (1993).

## 2 Theoretical discussion: main determinants of the propensity to innovate

In this section we present and discuss the main mechanisms (*see* Dosi (1988)) on which we will focus in order to develop our econometric model. When this is possible, we also establish connections with results already obtained in the literature, especially when they concern innovation processes in developing countries. Unfortunately, not many studies focus on this subject, mainly because of insufficient data.

### 2.1 Role of demand

The necessity to adapt to the market demand is an important motivation for innovation (Schmookler (1966)). Product innovations, but also process innovations, aim to propose a better adapted offer to the consumers, in terms of products and services.

In a developing country like Tunisia, we observe an inequality in the distribution of revenues, and hence of demand, an important share of the potential demand corresponding to relatively low and very low revenues. The Gini coefficient for Tunisia is around 41% and households with the 20% lowest revenues correspond to 7% of the total expenditures, while 20% with the highest revenues, to 47% (INS (2000))<sup>4</sup>. As a consequence, the firms must face a strongly asymmetrical and heterogenous demand. Moreover, the necessity of serving foreign markets (because of financial constraints imposed by the balance of payments), gives a considerable role to the foreign demand. Firms must innovate in order to be able to serve both domestic and foreign demand in order to attain satisfactory profit levels and, even more dramatically, to survive.

**Conjecture 1** *The necessity to be profitable while serving the low-revenue domestic demand, the firms must develop process innovations in order to reduce costs and prices. Reducing costs should be one of the motivations of process innovations.*

**Conjecture 2** *The necessity of serving both the domestic and foreign markets, and hence a heterogeneous aggregate demand, the firms must develop product innovations. A variable representing the proportion of exports in sales should have a positive effect on product innovations, with possible non-linearities.*

The relationship between innovations and exports can of course be quite complex, since there can be a self-selection bias due to the fact that innovating firms can more easily face international competition. Any result on this connection must be taken with some caution (Mohnen, Mairesse & Dagenais (2006)), especially because of the simultaneity of the answers in the survey on these points.

**Conjecture 3** *Determinants of process and product innovations must be differentiated because they are reflecting different motivations. Separately analyzing these two kinds of innovations can bring more insights.*

Results of Cabagnols & Le Bas (2002) and Kannebley et al. (2005) demonstrate the necessity of separately considering these two types of innovations (respectively for France and for Brazil).

### 2.2 Technology and absorptive capacity

Tunisia is not a supplier of technology and it does not directly contribute to the advancement of the world technological frontier. The capability of benefitting from this frontier is the main source of technological advance. This capability will be determined by the absorptive capacity of the firms

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<sup>4</sup>For comparison: the Gini index was 50.6% at Nigeria in 1997, 60% at Brazil in 1996 and 32.5% at France in 1995 (Source: World Bank (2004), *Beyond Economic Growth*).

(Cohen & Levinthal (1990)). As a consequence, the usual determinant of the innovative capacity, the internal R&D investment of firms, will also play an important role in the construction of their absorptive capacity and in their capability to benefit from external sources of technological knowledge.

**Conjecture 4** *The internal R&D activity of the firms is a necessary but not sufficient condition of technical progress. A variable representing the existence or the level of R&D effort of the firm should have a positive effect on innovations.*

We can hence expect that firms could innovate even if they do not carry formal R&D activities.

**Conjecture 5** *Firms benefit from external sources of technological knowledge (universities, organisations, other firms). Variables representing these channels of knowledge should have positive effects on innovation.*

We can expect some substitutability or complementarity between these external sources or between the R&D activities of the firms and these sources.

### 2.3 Firm size

The role of the firm size in the innovative capacity of firms is an old debate that is inspired by the contrast that exists between the analyses of Schumpeter (1934) (where small entrepreneurial firms are the main source of innovations) and Schumpeter (1942) (that underlines the necessity of being large for developing R&D activities and innovation). A very extensive literature exists on the connection between firm size and propensity to innovate (for a detailed discussion, see Cohen & Levin (1989) and Cohen & Klepper (1996)). Even if the results of this literature are quite far from conclusive for industrial countries, the size of firms, especially for a developing country like Tunisia, could play an important role, since it would be an important determinant of the financing capacity of firms. Moreover, a bigger firm will more frequently have to solve process problems, and hence, introduce new processes.

Üçdoruk (2005) finds a positive influence of firm size on innovative propensity for a similar country (Turkey) and Kannebly et al. (2005) observes the same effect for Brazil.

**Conjecture 6** *Bigger firms must be more innovative. Firm size should have a positive effect on innovation, probably more for process innovations.*

We can also expect some non-linearity since Goedhuys (2007) observes that medium sized firms are the most innovative.

### 2.4 Public ownership

The participation of the state can also play an important role in a developing country, because it can assure to firms financial and institutional support. This possibility is underlined by several studies but without yielding a general result. We can not exclude that this support can also imply a stronger hold of bureaucracy on the firm and reduce its dynamism.

**Conjecture 7** *Participation of the state to the capital of firms can increase their innovative capacity (with a probable contrary negative impact due to bureaucracy).*

We now describe the main characteristics of our database and present our methodology.

## 3 Dataset, model and methodology

We first present the dataset we use in this article. The discussion of the methodology we have adopted is presented in a second paragraph.

### 3.1 Overview of the dataset

The analysis is based on micro data from the Innovation Survey provided by MSRTCD which surveyed firms on various aspects of their innovation activity from 2002 to 2004. Following the Oslo Manual, a harmonized questionnaire inspired from the Community Innovation Survey (CIS) was used to collect the data. Since the focus is to uncover factors that favor innovation capacity of Tunisian firms, the survey was targeted in a manner to cover the maximum of firms likely to have an innovative and/or R&D activity. The choice of the population was restricted to:

- manufacturing firms with high technological intensity and/or strong added value;
- firms having manpower higher than 10 people;
- firms filed by the Industry Promotion Agency and the National Institute of the Statistics.

The targeted population includes 900 firms. The confrontation with the national directory of the National Institute of the Statistics leads to a final list of 739 firms. Among them 586 firms answered the questionnaire with a rate of answer equal to 79%. The database contains the direct answers of the firms, without any obfuscation through micro-aggregation methodology used by some other CIS surveys (Mohnen et al. (2006)).

Many questions are of the Yes/No type and their data is represented by binary variables. Our main variables (product and process innovations) are of this type: firms are asked if they have introduced a new product or process during the three years preceding the survey. Table 1 gives the descriptive statistics (the mean and the standard deviation) of the variables used in this article. We also indicate the type of each variable: binary or continuous.

This survey has many shortcomings. It shares the common deficiencies of the CIS inspired surveys (many qualitative variables, subjective questions difficult to interpret, etc.), but it also has some specific shortcomings: this is the first innovation survey in Tunisia and it constitutes just an observation point, without any dynamic dimension that would allow panel data analysis ; some questions propose items difficult to interpret by the respondents or items that do not belong to the same level of causality (like mixing mid-term strategic dimensions with immediate consequences of decisions). Nevertheless, this survey is precious since it allows a first outlook to the innovation process of Tunisian firms. A second survey is in preparation and it should solve some of these problems.

### 3.2 Methods of analysis

We combine two different statistical methods to analyze the main determinants of innovative activity in Tunisia: PROBIT models and regression trees. The statistical analysis is realized using R-Project (R Development Core Team (2003)) and Stata.

Probit models belong to the class of latent variable threshold models for analyzing binary data. They assume that the binary response is the indicator of the event that an unobserved latent variable exceeds a given threshold that is sufficient to induce the innovation of the firm.

exceeds a given threshold. We represent "Innovation" by a binary dependent variable, which is equal to 1 if the firm answers positively the question on the introduction of a product/process innovation during the three years preceding the survey, or equal to 0 if the answer is negative. The parameters of the Probit are estimated using Maximum Likelihood procedure. We use the probit estimations of the independent variables' marginal effects in order to interpret their relative effects. The validation of our theoretical specification, of its efficiency and of its robustness is done through a set of appropriate tests (normality, specification, adjustment quality and global signification<sup>5</sup>). The explanatory variables of the probit models are chosen following the conjectures of section 2.

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<sup>5</sup>Detailed statistical results can be consulted at the following address  
<http://www.vcharite.univ-mrs.fr/PP/yildi//files/appendixunis1b.pdf>



Variable	All firms		innovprod=1		innovProc=1	
	mean	sd	mean	sd	mean	sd
<b>innovall</b>	0.61	0.49				
<b>innovproc</b>	0.49	0.50	0.70	0.46		
<b>innovprod</b>	0.41	0.49			0.59	0.49
betterWorkCond	0.60	0.49	0.70	0.46	0.71	0.45
collInternatOrg	0.13	0.33	0.22	0.42	0.20	0.40
collLabUnit	0.08	0.27	0.09	0.29	0.09	0.28
collNatOrg	0.15	0.36	0.21	0.41	0.22	0.42
collOtherFirms	0.12	0.32	0.17	0.38	0.16	0.37
collRecCent	0.07	0.26	0.09	0.29	0.09	0.29
collUniv	0.11	0.31	0.18	0.39	0.15	0.36
ConsultTechn	0.41	0.49	0.58	0.49	0.59	0.49
decCosts	0.59	0.49	0.70	0.46	0.72	0.45
decEnvImpact	0.34	0.48	0.42	0.49	0.43	0.50
depRD	0.54	0.50	0.72	0.45	0.65	0.48
envirFriendProd	0.21	0.41	0.28	0.45	0.29	0.46
Export (%,* )	46.61	45.24	38.81	41.77	44.27	43.67
extendProdScope	0.57	0.50	0.83	0.38	0.75	0.43
flexibleProd	0.34	0.47	0.42	0.49	0.47	0.50
incProductivity	0.65	0.48	0.78	0.42	0.79	0.41
incQuality	0.72	0.45	0.89	0.31	0.90	0.30
lnSales (* )	15.29	1.76	15.65	1.57	15.64	1.61
openNewMarkets	0.61	0.49	0.80	0.40	0.78	0.41
partState (%,* )	7.17	25.09	5.11	21.52	6.08	22.87
partialExporter (PE)	0.35	0.48	0.49	0.50	0.44	0.50
preserveMarkShare	0.58	0.49	0.72	0.45	0.71	0.46
replaceProduct	0.17	0.38	0.27	0.44	0.22	0.41
Observations	586		240		285	

Table 1: Summary of the dataset variables. The table gives the mean and the standard deviation of each variable. All variables are binary except when signalled by (\*) for continuous variables.

Probit results indicate the global role of the variables in the determination of the propensity to innovate. We use non-parametric regression trees to partition our observation space in order to analyze the interaction between variables and the possible complementary or substitutable relationships between them.

Non-parametric regression trees are useful for detecting important variables, interactions and identifying outliers. They are also very useful as an exploratory tool for analyzing the interaction between explanatory variables of a model. A regression tree (Venables & Ripley (1999), chap10) establishes a hierarchy between independent variables using their contribution to the overall fit ( $R^2$ ) of the regression. More exactly, it splits the set of observations in sub-classes characterized by their values in terms of their contribution to the overall fit and of their predictions for the dependent variables. This value is validated against a fraction (10%) of the sample that is not used in the estimation. The value at which this partitioning is stopped (and the tree cut) is given by the complexity parameter ( $cp$ ). Regression trees are very flexible and powerful in the clarification of the structure of the observations. The tree gives a hierarchical sequence of conditions on the independent variables of the model: the higher the role of a condition in the classification of the observed cases, the higher its status on the tree. For each condition, the left branch gives the cases for which the condition is true and the right branch gives the cases that are compatible with the complementary condition.

## 4 Results

We first analyze the declared motivations of firms for engaging in innovative activities. This helps us to have some limited indications about how firms view their R&D activities. This analysis shows that they follow different objectives for product and process innovations. We therefore analyze in a second paragraph the determinants of these two types of innovations, on the light of our theoretical conjectures.

### 4.1 Motivations of innovations

A question of the survey asks firms if they have been engaged in R&D activities during three years preceding the survey, with the aim of: replacing products; extending product scope; creating more environmentally friendly products; preserving market share; opening of new markets; having a more flexible production process; reducing costs; improving quality; creating better working conditions; increasing productivity; decreasing their environmental impact.

We observe that these motivations do not all concern the same level of objectives for the firm: some are clearly strategic (like preserving market shares or opening new markets), but others directly concern a specific type of innovation (like replacing products or increasing product scope). Some could also have some redundancy on the eyes of the firms since, for example, increasing productivity and decreasing costs are not totally independent motivations.

We start the analysis using partial correlation coefficients between these motivations and the innovations. The first columns of Table 2 show that firms' motivations are quite different between product and process innovations (confirmation of Conjecture 3). Moreover, these results indicate that firms do not globally and naturally connect strategic motivations like preserving their market share (line 4 of the table) or opening new markets (line 5) with their R&D activities. We also observe that motivations linked to the production process of firms are complementary, even if they are not all directly correlated with process innovations.

We can obtain a finer grained picture of the relationships between motivations if we partition the observations set using regression trees with product and process innovations as dependent variables.

Tree 1 shows that the main motivation for product innovations is the desire to extend the product scope. The highest expected probability of innovating is observed on right side of the tree, when

	Motivation	Innovation type		1	2	3	4	5	6	7	8	9	10
		Product	Process										
1	replaceProduct	0.13		1									
2	extendProdScope	0.28		0.16	1								
3	envirFriendProds			0.18	0.12	1							
4	preserveMarkShare				0.16	0.12	1						
5	openNewMarkets				0.22		0.16	1					
6	flexibleProd		0.13	0.11		<b>0.30</b>	<b>0.34</b>	0.19	1				
7	decCosts					0.13	0.18	0.22	<b>0.36</b>	1			
8	incQuality		0.11	0.15	0.11	0.14	0.16		0.28	0.27	1		
9	betterWorkCond					0.13	0.14	0.17	<b>0.37</b>	<b>0.43</b>	<b>0.40</b>	1	
10	incProductivity			0.12	0.15	0.13	0.28	0.23	<b>0.40</b>	<b>0.39</b>	<b>0.43</b>	<b>0.62</b>	1
11	decEnvImpact					<b>0.52</b>			<b>0.30</b>	0.19	0.14	<b>0.34</b>	0.23

Table 2: Partial correlation coefficients (significant for  $\alpha = 5\%$ ) between innovation success and motivations of innovating firms

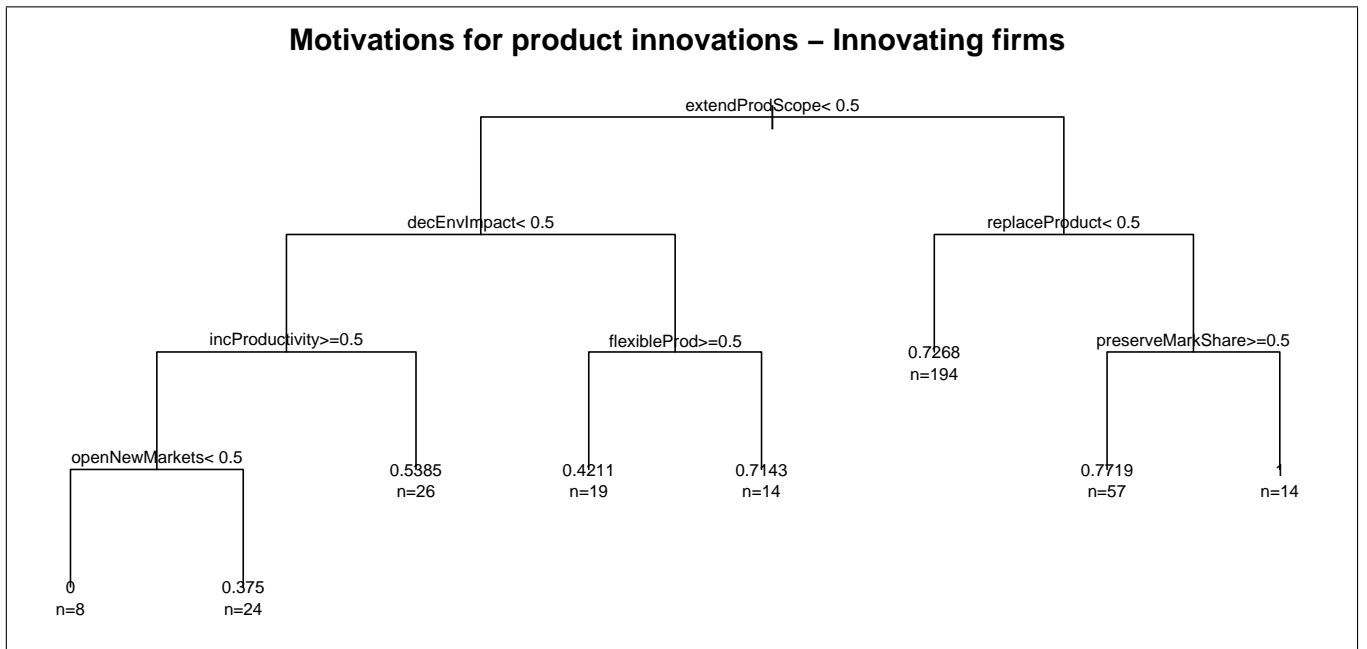


Figure 1: Regression tree for the motivations of product innovations ( $cp = 0.005, maxdepth = 5$ ).

firms desire to extend the product scope (265 innovating firms follow this strategy), and to replace existing products (57 firms are motivated by both strategies). Other 194 firms that only follow the first strategy ( $extendProdScope = 1$ ) can nevertheless attain a significant expected probability of product innovation (0.73). These results are not very surprising and they are in-line with the partial correlation coefficients observed in the first column of Table 2. Moreover, when firms are not following a defensive strategy (trying to preserve their market share that is more surprisingly unfavorable also to process innovations, as we will see below), they can attain even the highest expected probability of product innovation:

$$\left. \begin{array}{l} extendProductScope = 1 \\ replaceProduct = 1 \\ preserveMarkShare = 0 \end{array} \right\} \Rightarrow E(P[innovProd]) = 1, n = 14.$$

On the left side, we observe that firms that only aim to increase their productivity, without taking care of another dimension, are the worst innovators in product, with an expected probability of 0:

$$\left. \begin{array}{l} extendProdScope = 0 \\ decEnvImpact = 0 \\ incProductivity = 1 \\ openNewMarkets = 0 \end{array} \right\} \Rightarrow E(P[innovProd]) = 0, n = 8.$$

Only 8 firms correspond to this strategy. We also observe that another process based motivation, making the production more flexible, plays against product innovations.

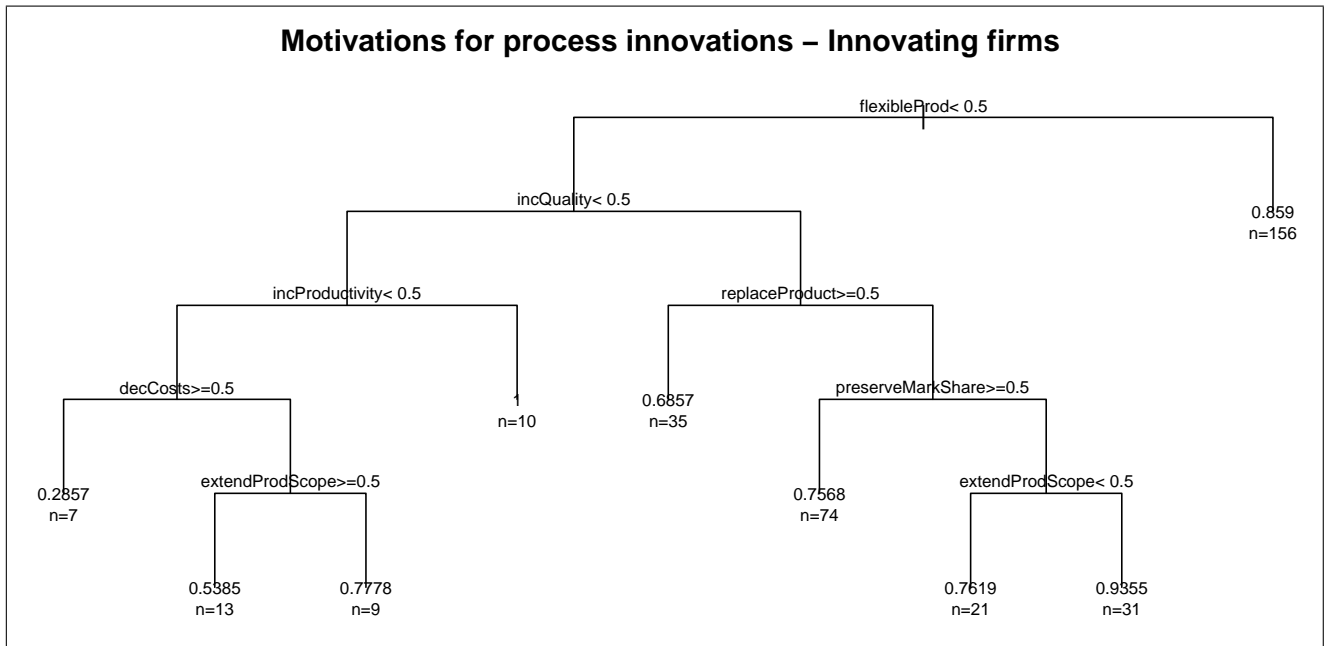


Figure 2: Regression tree for the motivations of process innovations ( $cp = 0.005, maxdepth = 5$ ).

On the contrary, in the tree of Figure 2 we observe on the left side that firms are very good performers in process innovations if they exclusively follow the objective of increasing their productivity:

$$\left. \begin{array}{l} flexibleProduct = 0 \\ incQuality = 0 \\ incProductivity = 1 \end{array} \right\} \Rightarrow E(P[innovProc]) = 1, n = 10.$$

But a significative number of innovating firms (156 firms) follow a different objective (the right branch of the tree): they attain an expected innovation probability of 0.86 by aiming to increase the

flexibility of production. This predominant role of production flexibility is rather surprising for a developing country. Cabagnols & Le Bas (2002) observe the same result for France, but the conditions of the Tunisian economy should be quite different, given the particularities of the distribution of revenues and the necessity of serving the demand corresponding to low revenues. Such a necessity would imply a desire to decrease costs. This motivation appears only on the left side of the tree, at a very low level. These results tend to reject Conjecture 1. The second highest expect probability is observed when firms are not motivated by the flexibility or by preserving their market share, but they desire to extend the product scope by increasing the quality of the products

$$\left. \begin{array}{l} flexibleProduct = 0 \\ \mathbf{incQuality} = \mathbf{1} \\ replaceProduct = 0 \\ preserveMarkShare = 0 \\ \mathbf{extendProdScope} = \mathbf{1} \end{array} \right\} \Rightarrow E(P[innovProc]) = 0.94, n = 31.$$

These results indicate that product innovations are directly motivated by the search for new products, while process innovations are driven by the desire to make the production process more flexible and by the objective of increasing the quality of products. As a consequence, the motivations for process and product innovations are quite different, and that should imply different mechanisms in their determination (Conjecture 3). The next section is dedicated to the analysis of the determinants of these innovation processes.

## 4.2 Determinants of innovations

We use a simple econometric model that is based on the theoretical conjectures, and conditioned by the constraints imposed by the nature of the survey. We use a probit model in which the probability of innovation is conditional to the following variables (we indicate the corresponding conjecture and the expected sign of the influence of the variable):

- Existence of an R&D department (*depRD*, Conjecture 4, +);
- Sales of the firm representing its size on the market (*log(Sales)*, Conjecture 6, +);
- Export ratio of the firm (*exports*) and, subsequently, a dummy indicating if the firm is a partial exporter that serves both domestic and foreign markets (*partialExporter*) (Conjecture 2, +);
- Participation of the State in the capital of the firm (*partState*, Conjecture 7,  $\pm$ );
- Channels of external technical knowledge (Conjecture 5, +):
  - universities (*collUniv*);
  - research centers (*collRecCent*);
  - laboratories and research units (*collLabUnit*);
  - national organisms (*collNatOrg*);
  - international organisms (*collInternatOrg*);
  - other firms (*collOtherFirms*);
  - external technical assistance (*consultTech*).

Table 3 gives the results of the probit estimations for the determinants of the product and process innovation success for all firms. The coefficients that are significant for  $\alpha \leq 5\%$ , are given in bold characters in the part A of the table (these results are also confirmed by a bivariate probit estimation). Part B of the table gives the marginal effects of significant variables.

	A-Coefficients		B- Marginal effects	
	Prod. innov.	Proc. innov.	Prod. innov.	Proc. innov.
R&D dept.	<b>0.47</b> (3.64)	0.23 (1.79)	<b>0.18</b> (3.73)	
log(Sales)	<b>0.08</b> (2.06)	<b>0.12</b> (3.34)	<b>0.03</b> (2.06)	<b>0.05</b> (3.34)
partialExporter	<b>0.38</b> (2.59)	0.10 (0.75)	<b>0.13</b> (2.59)	
partState	<b>-0.01</b> (-3.74)	<b>-0.01</b> (-2.65)	<b>-0.005</b> (-3.75)	<b>-0.003</b> (-2.65)
collUniv.	<b>0.57</b> (2.60)	0.24 (1.15)	<b>0.22</b> (2.66)	
collRecCent	-0.25 (-0.95)	-0.11 (-0.44)		
collLabUnit	-0.27 (-1.12)	-0.37 (-1.62)		
collNatOrg	0.26 (1.54)	<b>0.51</b> (2.99)		<b>0.20</b> (3.15)
collInternatOrg	<b>0.87</b> (4.33)	<b>0.57</b> (2.86)	<b>0.34</b> (4.74)	<b>0.22</b> (3.08)
collOtherFirms	0.29 (1.54)	0.30 (1.61)		
consultTech	<b>0.49</b> (3.84)	<b>0.64</b> (5.09)	<b>0.19</b> (3.88)	<b>0.25</b> (5.28)
constant	<b>-2.21</b> (-3.74)	<b>-2.45</b> (-4.39)		
Nb. obs.	538	538		
LR $\chi^2_{11}$	141.04	110.9		
Pseudo $R^2$	0.19	0.15		

The  $z$  - values are given below coefficients, between parentheses.

The marginal effect are given only for the significant coefficients.

Table 3: Determinants of product and process innovations of all firms (Probit results, in bold characters if significant for  $\alpha = 5\%$ )

If we first consider the sign of these coefficients, the results show that certain variables play a role for both types of innovation: size of the firms ( $\log(Sales)$ ), technical information received from international organisms ( $collInternatOrg$ ), help from technical consulting organisms ( $consultTech$ ), that are favorable to both types of innovation, and participation of the state in the capital of the firm ( $partState$ ), which is unfavorable to both. The role played by the size of the firms and the source of external technical information conforms to our initial theoretical assumptions (respectively, Conjectures 6 and 5). The bureaucratic effect of the state implication dominates its support effect (Conjecture 7). But we observe that internal R&D only plays a role for the product innovations and the process innovations rely mainly on external knowledge sources (so, Conjecture 4 is only partially confirmed). Two of these external knowledge sources also play a differentiated role: collaboration with universities is necessary for product innovations, while collaborations with national organisms are only beneficial to process innovations (see below a more detailed discussion of the respective roles of these sources).

Another important result concerns the role of exportations. If we directly include the proportion of the sales that are exported, we observe that this variable is not significant (that rejects the first part of the Conjecture 2). But this does not necessarily mean that exportations do not play a role. In fact, their role is non-monotonic: the least innovative firms are the ones purely dedicated to the domestic market or to the foreign market. What really counts for innovation is the fact that the firm serves both the domestic and foreign markets. We call such a firm a "partial exporter" (in opposition with firms that only serve the domestic market and the ones that are exclusive exporters). The dummy variable  $partialExporter$  represents this effect: it takes the value 0 when the firm does not serve both markets, and the value 1 otherwise. We observe that this variable plays a significant role for product innovations, and confirms Conjecture 2: serving a heterogenous demand implies the creation of new and diversified products.

Part B of the Table 3 gives the marginal effects of the significant variables. We observe that higher sales have a stronger effect on process innovations than on product innovations. This can also result from the fact that bigger firms have more problems to solve for their processes. Firms also benefit more from technical consulting in accomplishing process innovations, but product innovations benefit more from international technical collaborations. The participation of the state also plays a stronger negative role for product innovations, indicating that bureaucratic dimension puts a stronger brake on this type of innovations.

Universities	Resolution of technical problems for the firm (Ph.D. and master theses)
National organisms	Technical assistance Certification Training Improving quality Product and process update
International organisms	Certification (ISO and others) Training Main branch of the society Design of products Technical assistance Foreign partners Marketing of patents

Table 4: Role of external technological knowledge sources. Extracted from their textual descriptions in the survey

We can better qualify the nature of external technical knowledge sources. Indeed, the analysis of the textual descriptions of the collaboration with external organizations gives some partial indi-

cations<sup>6</sup> about the respective role of these technical knowledge sources (see Table 4). Their main contribution is in technical assistance, training and conception of new products. Foreign organisms also directly contribute, since some of the interactions are with the main branch of the international corporation to which belongs the firm. Certification is also an important tool since it facilitates the access to foreign markets. These collaborations are mainly called for solving problems related to product innovations. This confirms the important role of the product related motivations, as it appeared in the analysis of the motivations of R&D activities.

Again the regression trees can help us to better understand the interaction between these factors and possible complementarity or substitutability that can exist between them in the accomplishment of innovations.

Figures (3,4) give the determinants of product and process innovations. They show that help from technical consulting organisms plays a very predominant role in both cases (that again confirms Conjecture 5).

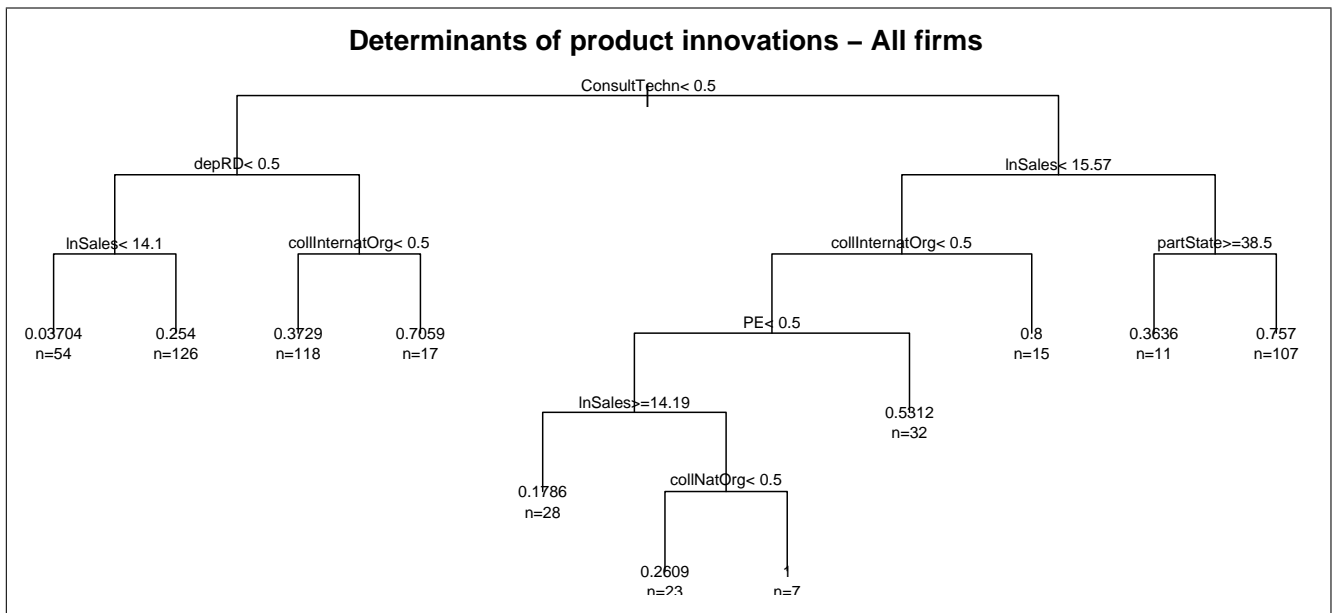


Figure 3: Determinants of product innovations ( $cp = 0.01$ ).

For product innovations (Tree 3), we observe on the most right branch that the biggest firms in the sample can attain high expected probability of innovation only if the state participation is low:

$$\left. \begin{array}{l} consultTechn = 1 \\ \log(Sales) \geq 15.57 \\ partState < 38.5\% \end{array} \right\} \Rightarrow E(P[innovProd]) = 0.76, n = 107.$$

This confirms the global negative role played by this last variable, and indicates a complementarity between the negative part of Conjecture 7 and Conjecture 6.

When firms are smaller, they can nevertheless attain a very high expected probability if they benefit from collaboration with international organisms, which, in this case, can constitute a substitute to the firm size:

$$\left. \begin{array}{l} consultTechn = 1 \\ \log(Sales) < 15.57 \\ collInternatOrg = 1 \end{array} \right\} \Rightarrow E(P[innovProd]) = 0.80, n = 15.$$

<sup>6</sup>These textual fields are provided by at most 86 firms (15% of the 586 firms in the sample).



The lowest probability ( $\approx 0.04$ ) is expected for smaller firms ( $\log(Sales) < 14.1$ ) that do not benefit from technical consulting, nor from internal R&D (the most left branch of tree). Not a very surprising result, since it corresponds to Conjectures (4, 5, 6).

A more surprising result concerns a very small set of 7 firms that benefit from the highest expected probability ( $= 1$ ):

$$\left. \begin{array}{l} \text{consultTechn} = 1 \\ \log(Sales) \in ]14.19, 15.57[ \\ \text{collInternatOrga} = 0 \\ \text{partialExporter}(PE) = 0 \\ \text{collNatOrg} = 1 \end{array} \right\} \Rightarrow E(P[\text{innovProd}]) = 1, n = 7.$$

These firms exhibit characteristics quite in opposition with the global conclusions of the probit estimations: they are specialized only on one type of market (4 on the domestic market and 3 on the foreign) and they do not benefit from international organisms. For these firms we observe that national cooperation is a substitute for international source of knowledge. Unfortunately, given the anonymity of the survey, we can not further analyze the very peculiar conditions characterizing these firms.

To summarize, firm size and different technical knowledge sources play the most determinant role for product innovations, with some substitutability between them (Conjectures 4, 5, 6).

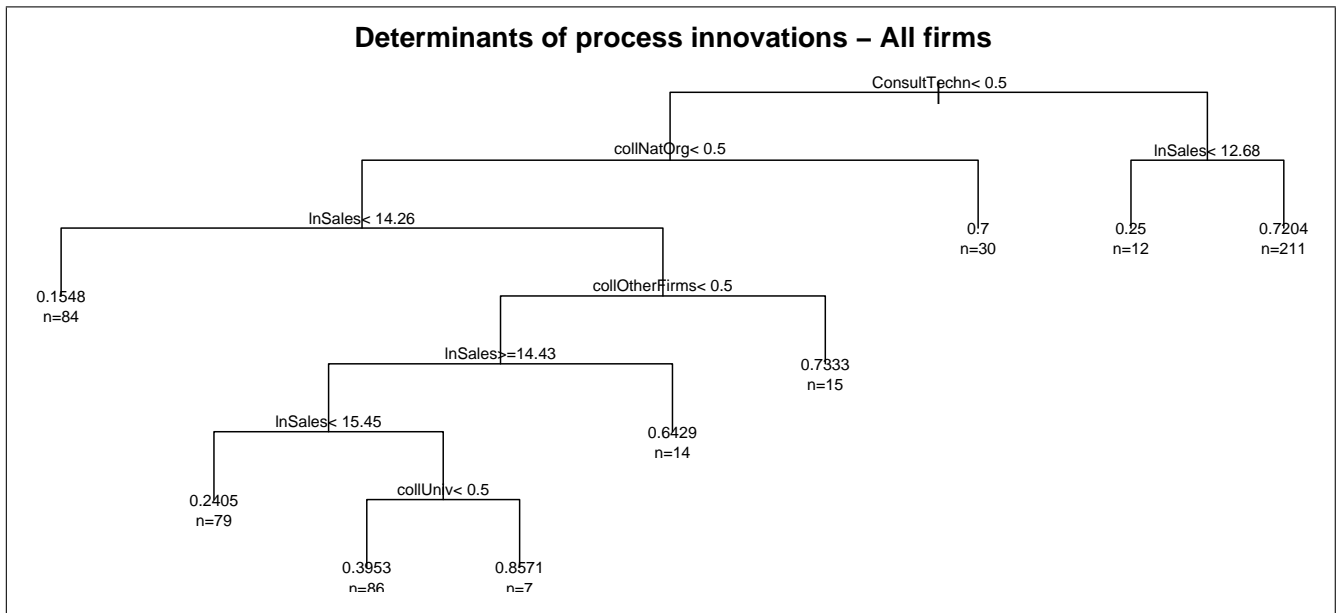


Figure 4: Determinants of process innovations ( $cp = 0.01$ ).

For process innovations, some substitutability between technological knowledge sources is also observable for the bigger firms. When firms benefit from technical consulting (the right branch), they can attain a high expected probability if they are not small:

$$\left. \begin{array}{l} \text{consultTechn} = 1 \\ \log(Sales) > 12.68 \end{array} \right\} \Rightarrow E(P[\text{innovProc}]) = 0.72, n = 211.$$

If firms do not access to technical consulting (the left side of the tree), they can attain high probabilities if and only if they can benefit from other external sources:

$$\left. \begin{array}{l} \text{consultTechn} = 0 \\ \text{collNatOrg} = 1 \end{array} \right\} \Rightarrow E(P[\text{innovProc}]) = 0.7, n = 30$$

or

$$\left. \begin{array}{l} \text{consultTechn} = 0 \\ \text{collNatOrg} = 0 \\ \log(\text{Sales}) \geq 14.26 \\ \text{collOtherFirms} = 1 \end{array} \right\} \Rightarrow E(P[\text{innovProc}]) = 0.73, n = 15$$

or

$$\left. \begin{array}{l} \text{consultTechn} = 0 \\ \text{collNatOrg} = 0 \\ \log(\text{Sales}) \geq 15.45 \\ \text{collUniv} = 1 \end{array} \right\} \Rightarrow E(P[\text{innovProc}]) = 0.86, n = 7.$$

As a consequence, these sources can play a substitutable role, but only if firms are not *too* small.

When firms do not benefit from any form of knowledge source and if they are small, we observe the lowest expected probability of process innovation:

$$\left. \begin{array}{l} \text{consultTechn} = 0 \\ \text{collNatOrg} = 0 \\ \log(\text{Sales}) < 15.45 \end{array} \right\} \Rightarrow E(P[\text{innovProc}]) < 0.25, n = 163.$$

One feature that arises from these results is the necessity of benefiting from some form of external technological assistance (Conjecture 5), independently from other dimensions. This assistance is even more essential than the internal R&D effort of firms. This is definitely a singularity of innovation processes in developing countries (Üçdoruk (2005) obtains a similar result for Turkey).

## 5 Conclusion

This is the first article dedicated to the systematic analysis of the innovation processes of firms in Tunisia. Using the first CIS based survey of Tunisian firms, we study the motivations and the determinants of product and process innovations in this developing country. Starting from theoretical conjectures based on the basic mechanisms of innovation processes, we formulate and test a set of conjectures on the particularities of this country. Using probit models and non-parametric regression trees, we observe that motivations of firms significantly differ between product and process innovations. Product innovations are mainly motivated by diversification strategies, while process innovations are driven by the objective of making the production processes more flexible and of increasing product quality.

The analysis of these two kinds of innovations shows the essential role played by external technical knowledge sources. Even if some complementarity exists between them, firms must be able to benefit at least from one of them to attain a significant innovation propensity. In contrast, the internal R&D plays a role only for product innovations. Firms size plays a positive role for both types of innovation, and the implication of the State in the capital of firms has a negative impact on innovation propensity. Small firms that do not benefit from any kind of technical assistance are condemned to lowest innovation capabilities. It is clear from these results that the reinforcement of all types of technical assistance to firms is indispensable for increasing the propensity to innovate of Tunisian firms. The negative role of the state implication should also be elucidated in order to correct its harmful role.

In this first article we have focused on the main basic mechanisms of the innovation processes. It is clear that a more through study must be dedicated to other dimensions. We will analyze the role of the openness of the firms in a second article. Even if it has several shortcomings, this first innovation survey of Tunisian firms is very precious since it gives interesting indications on the innovation processes in a developing country. Such surveys continue to be rare and their generalization should allow better comparative studies between developing countries, but also with industrial countries for which we begin to have a comprehensive collection of homogeneous surveys, even if more efforts are necessary to make them fully comparable.

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