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Les modèles sectoriels d'innovations dans un pays en développement : le cas de la Tunisie

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Résumé

Nous analysons dans cet article les principaux déterminants de dynamique technologique dans l'industrie manufacturière en Tunisie. Les données de l'enquête fournie par le Ministère de Recherche Scientifique, de la Technologie et du Développement de Compétence (MRSTDC) pendant la période 2002-2004 sont explorées en utilisant les arbres de régression et le modèle Probit pour déterminer les facteurs principaux qui favorisent la capacité innovatrice des firmes tunisiennes. Nos résultats montrent qu'il faut distinguer entre les innovations de procédés et les innovations de produits qui se conduisent par des mécanismes différents. De plus, nous observons que l'hétérogénéité sectorielle ne devrait pas être négligée et nous étudions plus en détail les 4 secteurs qui sont particulièrement bien représentés dans notre échantillon. Cette analyse nous permet de suggérer une politique différenciée pour favoriser la capacité innovatrice dans ces secteurs.

Mots-clés : Dynamique industrielle; Systèmes d'innovation; Economie de développement; Système sectoriel d'innovation

Sectoral patterns of innovation in a developing country: The Tunisian case

Abstract

We analyze in this article main determinants of technology dynamics in Tunisian manufacturing sectors. The data from the industrial survey provided by Ministry of Scientific Research, Technology and Competency Development (MSRTCD) for the period 2002-2004 is explored using regression trees and Probit models in order to discover main factors that favor the innovative capacity of Tunisian firms. Our results show that we must distinguish process and product innovations because they are driven by different mechanisms. Moreover, we observe that sectoral heterogeneity should not be neglected and we study more in detail fours sectors that are particularly well represented in our sample. This analysis allows us to suggest some differentiated policy indications for fostering innovative capacity in these sectors.

Key words: Industry dynamics; Innovation systems; Development economics; Sectoral systems of innovation

JEL : O120; O300

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1 Introduction

The relationship between internal research efforts, technological innovation and productivity growth has received a good deal of attention in the literature, with a number of studies having explored this issue. Since the late 1960s, numerous studies have been devoted to the determinants of technological innovation. They encompassed a large number of factors that affect the firm's innovation behavior. However, controversial viewpoints are discernible within the previous studies which do not provide clear guidance of what to expect in general. Since the 1980s, many contributions recognize that the determinants of innovation are subject to a number of moderating conditions such as the firm size, the industrial sector and the national environment (Souitaris 2002). The most frequently examined moderating factors are firm size, industrial sector, technological opportunities, market pull, technology push and degree of competition (*see* the next section). The notions of sectoral patterns of innovation and technological regimes, introduced by the evolutionary economists, suggests that industrial sectors provide an important level of analysis for an understanding of the dynamics of innovation and economic growth. These concepts aim to provide a multidimensional and dynamic view of sectors having specific knowledge base, technologies, inputs, and a potential or an existing demand. Indeed, this view of sectoral patterns may prove to be a useful tool for the identification of factors affecting the innovation rates and the competitiveness of firms in different sectors also for a developing country. The notion of technological regime dates back to Nelson & Winter (1982) and Pavitt (1984) that provide a framework for the description of the technological environment in which firms operate. Malerba & Orsenigo (1993, 1990) propose that a technological regime is a particular combination of some fundamental properties of technologies (opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, and the characteristics of knowledge base). The sectoral patterns of innovative activities may be explained as the outcome of different technological regimes that are implied by the nature of knowledge and technology and provide a synthetic representation of some of the most important economic properties of technologies and the characteristics of the learning process (Malerba & Orsenigo 1997).

The present work is oriented toward the study of the configuration of sectoral patterns of innovation of Tunisian firms, using micro-data from a recent innovation survey provided by the Ministry of Scientific Research, Technology and Competency Development (MSRTCD) in 2005[1]. Our approach is original in two aspects : on the one hand, this dataset allows us to analyze technology dynamics in a developing country as Tunisia; on the other hand, we combine an exploratory analysis based on non-parametric regression trees and an econometric approach based on Probit models. Our main objective is to understand the determinants of success in the innovation process of Tunisian manufacturing firms in order to propose guidance for national and sectoral technology policy. This is one of the first articles that propose a systematic analysis of the innovation dynamics in Tunisia.

In the empirical studies many difficulties lie in obtaining proper measures of elements combined to identify and describe different technological regimes. These classifications suffer from the absence of an econometric model of innovation behavior and remains essentially descriptive. To avoid these difficulties, we estimate the effects of covariates on predicting the ability to innovate using regression trees and discrete choice models. Our approach distinguishes the present work from the others which use innovating firms as unit of analysis and classify sectors of innovating firms that perform R&D expenditures according to the sources of knowledge, the technological opportunities, the means of appropriations and the accumulative nature of innovations. In fact, in developing economies all firms can not develop new and better products or production processes for the market and successfully commercialize them. Some innovations simply consist in introducing better products that are new only for the firm. Other firms make a specific effort and undertake R&D activities, but they fail to innovate. Thus, our analysis is not only restricted to the group of firms that undertake formal R&D activities, but covers all firms that relay on the introduction of novelty to face the market competition

[1]The authors are very grateful to Hatem Mhenni, National Observatory of Science and Technology, for providing the data

and demand. We also use information regarding non-innovating firms to provide guidance for policy measures to encourage firms to innovate. We take into account various indicators for innovation and sectoral diversity. Sectoral patterns are analyzed on the basis of a set of indicators which attempt to capture some of the essential features of innovations in developing countries. Then, we attempt to rely on our finding and conceptualization to analyze the innovation policy in Tunisia. Indeed, to day, there has been an increased interest by policymakers to understand the processes of innovation that underlie success and competitiveness of firms and countries. The firms positions in their markets are more challenged by the international competition which puts local firms under fierce *competitive pressure*.

Our econometric approach, combining regression trees and Probit models, enables us to identify and describe the variety of patterns of innovation behavior by estimating the effects of covariates on predicting the ability to innovate. This feature, helps us to explain and to describe the configurations of innovation process. We describe similarities and differences among firms and, thus, we try to provide a typology of Tunisian firms in accordance with the concept of technological regime taking into account sectoral innovation specificities. Our preliminary results indicate that Tunisia is not benefiting yet from a successful national innovation system and each sector implements specific strategies to benefit from demand pull and to face competitive pressure.

The next section summarizes the main determinants of innovation that have been underlined in the literature. The third section presents the dataset that we use, as well as the research methodology that we adopt to analyze it. The fourth section studies the factors that condition the global innovative capacity in the manufacturing sectors of Tunisian economy. We observe that it is mandatory to distinguish product innovations from process innovations and that sectoral heterogeneity can not be neglected. As a consequence, the fifth section is dedicated to the detailed analysis of the innovation process in four significant sectors. The last section concludes the article.

2 A quick literature survey of assumptions on innovative activity

There is a large body of literature available on determinants of product and process innovation. A scanning of this literature on types, determinants and performance of innovations shows that sectors may differ greatly in their innovative performance from these points of view. They may also differ in what they innovate in. Three main types of innovations are generally distinguished: Product, process and organizational innovations. Schmookler's (1966) demand theory still constitute a long-lasting controversy about technology-push versus demand-pull determinants of innovation in the economic literature (Unger 2005). The literature emphasizes many aspects of supply- and demand-sides, through variables that take globally into account the level and the variation of economic activity. Indeed, if firms expect that there will be a market for their new products or processes, they allocate resources to explore and develop new techniques of production or new products which may affect their market competitiveness, their production costs and, ultimately, the structure and performance of the industries (Dosi 1988).

The Schumpeterian model gives a plausible interpretation of competition in a range of important sectors. The intersectoral differences in the sources of innovations are related to the differing incidence of innovative competition between industrial sectors (Cooper 1994). Indeed, the sectors differ both in the rate and in sources of innovation. Dosi (1988) emphasizes the sectoral differences in technological opportunities, the degree of appropriability and the patterns of demand firms face, and these differences give rise to different modes of innovation. Table 1[2] summarizes the theoretical and empirical results concerning the principal determinants of product and process innovations. We meet some of these mechanisms in our analysis of the innovation dynamics in Tunisia.

[2] Source: Unger (2005), completed by the authors.

Table 1: Determinants of product and process innovation

Demand conditions:	
Lunn (1986)	Demand should influence product innovation more than process innovation.
Pavitt (1984)	Heterogeneous demand directed toward series should enhance product innovations.
Sources of technological knowledge:	
Cohen & Levinthal (1990)	Absorptive capacity helps firms to become process innovators.
Leo (1996)	National sources of technological knowledge should favour product innovation in a national system of innovation framework.
Levin et al. (1987)	Progress in scientific knowledge should influence both product and process innovations.
Pavitt (1984)	Product and process innovations are more frequent in science-based industries.
Reichstein & Salter (2006)	External sources of knowledge and cooperation with non academic partners are important for the process innovation
von Hippel (1988)	Process innovators often need to work closely with external suppliers in order to develop new technologies.
Zucker et al. (1998)	Connections to universities should stimulate product innovation in emerging technology.
Market structure and competition:	
Baldwin et al. (2002)	Foreign ownership and the number of competitors in an industry are all important factors in explaining why a firm is a process innovator.
Cabagnols & Le Bas (2002)	Firms belonging to highly concentrated industries are more likely to be process innovators than product innovators
Lunn (1986), Scherer (1983)	Concentration should be a characteristic of process innovation but not for product innovation.
Unger (2005)	Intensity of the technological competition: progressive sectors are more intense in technological competition than other sectors.
von Hippel (1982)	Product innovations are sensitive to the capacity of the firm to take advantage of the response time of its competitor.
Weiss (2003)	Firms favor product innovation where there is a high level of product differentiation and competition is severe. Process innovation will be undertaken where products are less differentiated and there is less competition in the industry.
Boone (2000)	A rise in competitive pressure cannot raise both product and process innovations at the industry level.
Characteristics of the firm:	
Baldwin et al. (2002)	Large firms invest more in process innovation than small firms.
Cohen & Klepper (1996)	Large firms are more likely to be process innovators.
Leiponen (1999*a*)	Product innovation requires workers with more diversified skills than process innovations
Leiponen (1999*b*)	Product innovators tend to benefit more from collaboration with suppliers. Process innovators are more likely to benefit from collaboration with universities.
The firm's strategy:	
Cabagnols & Le Bas (2002)	Strategic focus on product ”flexibility” and ”quality” was characteristic of process innovators.
Klevorick et al. (1995)	Firms oriented towards improvement of product and process technical characteristics induce process innovations. Trajectories are characterized by the filling of demand, resulting in product innovations.

3 The data set and our research method

The data used in this paper are drawn from a survey provided by Ministry of Scientific Research, Technology and Competency Development (MSRTCD) for the period 2002-2004. The data covers 586 Tunisian firms with at least 10 employees. The database consists on 529 observations of manufacturing industry. This survey enables us to overcome the problems associated with the exclusive use of R&D (innovation input) or patents (innovation output) as a measure of technological behavior. Indeed, innovation behavior patterns may be characterized in terms of a set of driving forces for innovation, and not only on the base of the balance between product and process innovations (Marsili and Verspagen, 2001). Even if the questions of the survey are not always very detailed (concerning the past activities, for example), it concerns quite a large sample for Tunisia and can be used for a first analysis of innovation dynamics. A second survey with more detailed questions is in preparation.

Table 2 reports variables used in this study. Sample statistics turn out that 356 (60.75%) firms have at least one innovation. 239 Firms (40.78%) have technological and scientific cooperation and 316 (53.92%) have R&D, design or method department.

Table 2: Variables Used in the Study

Innovprod	Dummy for a new product introduced in the market
Innovproc	Dummy for a process innovation
Innovall	Dummy for a process **or** a product innovation
RDForce	Technical workers on R&D
partState	Public capital in firm (in percent)
partForeign	Foreign capital in per cent
pullEffect	Demand Pull factor
compPressure	Competitive Pressure factor
depRD	Dummy for R&D department
Cooperate	Dummy for technological and scientific cooperation
Sales	Sales in million dinars
Export	Share of exportation in sales
manufact	Dummy for manufacturing and energy sector
sector	Industrial sector

NB: A product innovation is a new product introduced in the market

We analyze this dataset using a combination of complementary statistical methods: Standard principal components analysis (PCA); Regression trees; PROBIT models. The statistical analysis is realized using R-Project (R Development Core Team 2003) and Stata.

Table 3: Factor analysis of innovative activities

Items / Factors	**compPressure**	**pullEffect**	**envirnEffect**
replace the products which are removed	-0.0840	**0.6102**	0.3355
extend the line of products	0.2082	**0.7678**	0.0612
develop products without danger to the environment	0.0636	0.1713	**0.8637**
sustain the market share	0.3887	**0.5234**	0.0931
access to new markets	0.4585	**0.5463**	0.0387
increase production flexibility	**0.5248**	0.1813	0.4319
decrease the production costs	**0.6831**	0.1685	0.1856
improve product quality	**0.6854**	0.3046	0.1132
improve the working conditions	**0.8205**	0.0019	0.1925
improve the productivity	**0.8092**	0.2000	0.1219
reduce the environment attacks	0.3269	-0.0338	**0.7703**
proportion (%)	27.84	15.99	15.92
cumulative proportion (%)	27.84	43.83	59.75

The results of principal-component factors analysis are given in Table 3. For these factors influencing innovation activities, a question has been asked: "During these 3 years (2002-2004) have you started an activity having for objective ... [the corresponding factor]?". Each principal component (axis) explains a linear combination of a group of interrelated variables having the greatest contribution to the axis. The first principal component accounts for the maximum of the variance in the data. Indeed, the first two axis show that these factors correspond to what would be easily considered as respectively the competitive pressure (*compPressure*) and the demand pull (*pullEffect*) effects. Given the significance of these two factors we privilege them in our analysis, in accordance with the theoretical guidance of *demand pull* and *technological push* theories. Even for sectoral analysis, we will use these global factors in order to preserve the comparability of competitive situations across sectors.

Regression trees and Probit models are used for determining the variables that condition the probability of innovation at global and sectoral levels.

Non-parametric regression trees are useful for detecting important variables, interactions and identifying outliers. They can be useful as an exploratory tool of modeling. A regression tree (see Venables & Ripley 1999, chap.10) establishes a hierarchy between independent variables using their contributions 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 during the estimation. 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 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.

Regression tree modeling is an exploratory technique for uncovering structure in data, increasingly used for devising prediction rules that can be repeatedly evaluated and summarizing large multivariate data sets by a recursive partitioning. We give, in the next section, a step-by-step interpretation of the main elements of the regression tree exposed in Figure 1 and the corresponding Probit regression.

Probit models belong to the class of latent variable threshold models for analyzing binary data. They arise by assuming that the binary response is the indicator of the event that an unobserved latent variable exceeds a given threshold. In our case the dependent variable is the probability of innovation ($P[I = 1]$). It is also possible to estimate the marginal contribution of independent variables to this probability. For these estimations, we of course also proceed with all necessary tests for validating their robustness (normality, specification, adjustment quality and global signification). Regression trees and economic theory (*see* the previous section) provide the base on which we choose the explicative variables that we retain in our Probit models.

Combining these two tools is particularly interesting for throwing light on the determinants of innovation. Indeed, regression trees shed light on variables that play a significant role in the innovative capacity of the firms and partition the sample in quite a fine way in order to observe joint effects of these variables. Then, PROBIT models, using these variables, discriminate effects that are robust at the level of whole sample. As a consequence, we can shad light both on effects that are global and robust, and those which are finer and only play locally under some conditions resulting from the combination of variables (effects that only appear when the $pullEffect$ is low, for example).

We begin our analysis at the global level covering all sectors and all types of innovations. We quickly observe that we need to distinguish product and process innovations since they depend on different sets of factors. Moreover, sectoral heterogeneity also appears as an important determinant of innovative behavior. In fact we include in the analysis the sectors to which firms belong as a possible explanatory factor. The name of these sectors is coded using the nomenclature given in the Table 4. In the section 5, our analysis is limited to four sectors AFI, MMI, EEEAI and TCI that are better represented in our sample (*see* Table 11 and Table 12 in the appendix).

Table 4: Nomenclature for the industrial sectors

AFI	Agri–Food Industries
BMCGI	Building Materials, Ceramics and Glass Industries
CHI	Chemical Industries
CPI	Car Parts Industries
EEEAI	Electrics, Electronics and Electrical home Appliance Industries
IA	Informatics Activities
ITC	Information and Techn. Communication
LSI	Leather and Shoe Industries
MEI	Mine and Energy Industries
MI	Miscellaneous Industries
MMI	Mechanical and Metal Industries
PI	Plastic Industries
PPCI	Pulp, Paper and Cardboard Industries
T	Transport
TCI	Textile and Clothing Industries
WFI	Wood and Furniture Industries

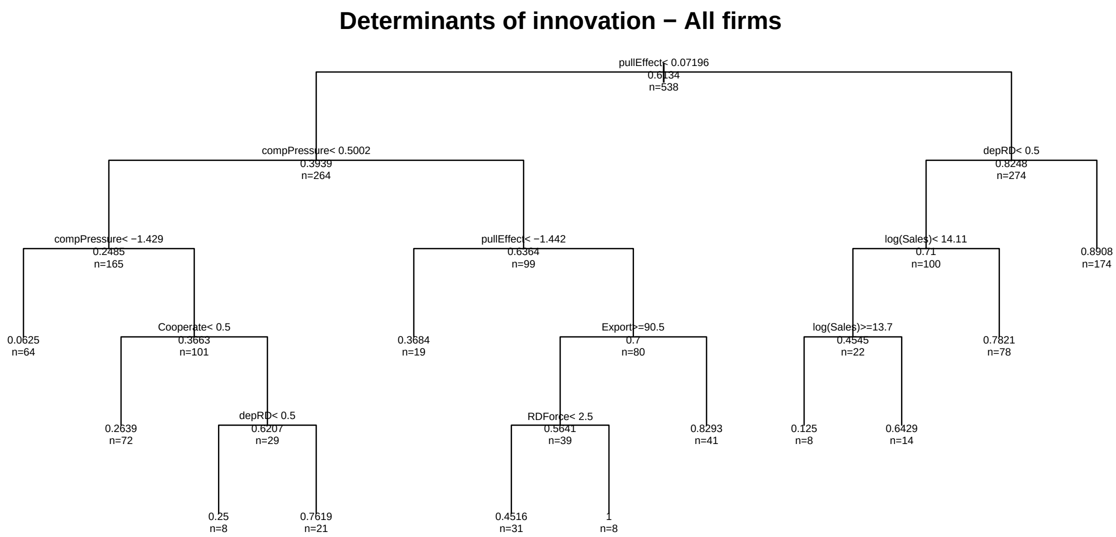


Figure 1: Global determinants of innovation

4 Global determinants of innovation

4.1 Main determinants of global innovation capabilities

We first consider the firms global capacity to innovate. We exclude cases with missing explanatory variables. The Figure 1 gives the regression tree for the success of innovation (success if a product innovation **or** a process innovation has happened). The following variables are used as potential determinants: *partState*, *partForeign*, *pullEffect*, *compPressure*, *RDForce*, *depRD*, *Cooperate*, *log(Sales)*, *Export*, *manufact*, *sector*. Only some of them finally appear in the tree.

The first branching distinguishes the observations with ($pullEffect < 0.07196$) on the left and the complementary cases ($pullEffect \geq 0.07196$) on the right.

The second level branching **on the right** shows that for the observations corresponding to $pullEffect \geq 0.07196$, firms with an internal R&D department have an expected probability to innovate of $P[I = 1] = 0.8908$ and we have $n = 174$ observations satisfying these conditions. Firms without an R&D department are nevertheless able to insure a probability of innovation higher than 78% if they are big. This result implies that a sufficiently important $pullEffect$ insures a very significant possibility for innovation when firms are big.

Table 5: Determinants of maximal expected innovation probability

	innovall	**innovprod**	**innovproc**
max prob	1	1	0.72
pullEffect	weak	high	not too weak
compPressure	not too weak		not too weak
depRD		not present	
R&D Force	more than 3		
partForeign		lower than 100%	
Export	more than 90%		
Sales		not too low	not too low
nb. firms	8	11	203

The **left side** of the tree exhibits a much more complex causality structure: $compPressure$, $Cooperate$, $Export$, $depRD$ and $RDForce$ all play a significant role in the determination of the probability of innovation. When both the demand pull and the competitive pressure are very low ($pullEffect < 0.07196$ and $compPressure < -1.429$), the innovative capacity is quasi nil. When firms are submitted to insufficient competitive pressure and very low demand pull, only firms beneficent from external cooperations and with R&D department are able to attain significant innovative capacities ($P[I = 1] = 0.7619$). However, when competitive pressure is not too weak, not to be exclusively dedicated to foreign markets may insure a high innovative capacity ($P[I = 1] = 0.8293$). Nevertheless, the presence of an internal R&D force is a necessary condition for a significant probability of innovation ($P[I = 1] = 1$) for firms quasi-exclusively oriented toward foreign market.

The first column of table 5 qualitatively summarizes global results for the case most favorable to innovation (corresponding to the highest expected innovation probability): a case where the competitive pressure is not too weak and firms are export oriented and with R&D force not too low.

Table 6: Probit regressions: global determinants of innovations

	All innov.		Prod. Innov.		Proc. Innov.	
	Coeff.	Marginal	Coeff.	Marginal	Coeff	Marginal
pullEffect	0.60**	0.22**	0.56**	**0.21****	0.42**	0.17**
CompPressure	0.45**	0.17**	0.27**	0.10**	0.41**	**0.16****
Dep R&D	0.42**	0.15**	0.49**	0.18**	0.20	0..08
Cooperate	0.47**	0.17**	0.29*	0.11*	0.30*	0.12*
Export	-0.00	-0.00	-0.00	-0.00	0.00	0.00
log(Sales)	0.12**	0.04**	0.07	0.02	0.11**	0.04**
Constant	-1.80**	-	-1.65**	-	-1.97**	-

Significance levels: $**$: 1% $*$: 5%

We consider more in detail the role of these variables in the rest of the article but we can already focus on four variables that play a prevalent role in all cases we study in the article: $pullEffect$, $compPressure$, $Cooperate$ and $depRD$ (or $RDForce$). The role of these variables and the robustness of the exploratory results of the trees can also be checked using Probit models. The first two result columns of Table 6 indeed show that these variables are all significant and, at the global level, the variable with the highest marginal (and positive) effect on the probability of innovation is $pullEffect$: the demand for product renewing and diversification is a main determinant of innovation. We also include *Export* in the analysis since it appears in the global regression tree but we observe below that its effect is not significant in several cases.

Proposition 1 (Global innovation capacity)
At the global level (including all firms and all innovations), the innovation capacity is significantly and positively dependent on the following variables: $pullEffect, CompPressure, depRD, Cooperate$ and $log(Sales)$. The strongest factor corresponds to demand pull and the existence of an internal R&D department is necessary for the highest innovative capacity. Nevertheless, a higher competitive pressure is a sufficient condition to be efficient in innovation if firms do not totally dedicated to foreign markets. Firms export oriented and under fierce competitive pressure have a very high innovative capacities if they employ sufficient manpower in R&D.

Table 7: Predicted innovation probs.

	Reg.tree	**Probit**
Global innovation	0.61	0.65
Product innovation	0.41	0.38
Process innovation	0.50	0.49

Table 7 compares predictions for the innovation probability in trees and Probit regressions. It shows the conformity and the robustness of the two complementary methods we use in this article.

The second and third results blocks of the Table 6 show that the determinants of product and process innovations are all significant and positive, but these variables play relatively contrasted roles (see also Table 5) and we must separately study these two fundamental types of innovation.

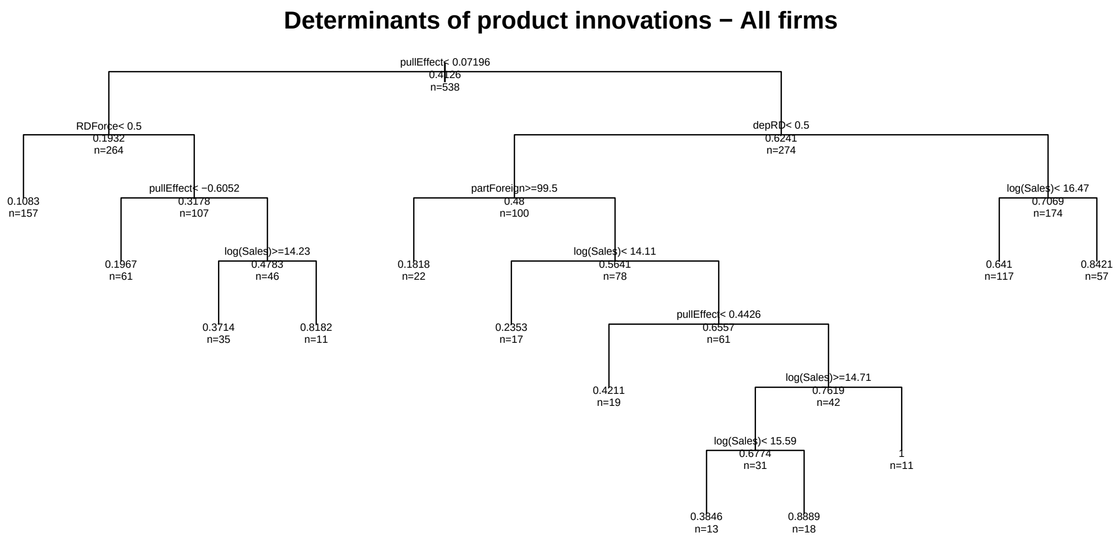


Figure 2: Global determinants of product innovation

It is also interesting to observe that Cooperation plays an important role when both types of innovations are considered, without necessarily playing a separated role in each case (it does not figure at all in the trees of Figures (2 and 3) but it is significant at the global level for each innovation type as this is shown by the results of the PROBIT models). However, when we include the variable *sector* in the trees (6), they clearly show the important effect of Cooperation only on product innovation rather than on process innovation (this results also is confirmed below).

4.2 Nature of innovations

Our global results show significant differences between product and process innovations, especially concerning the marginal effects of variables (Table 6): the effects of demand pull and competitive pressure on innovative capacity are much stronger for product innovations than process innovations (*see* Figures 2 and 3). The marginal effect of demand pull is weaker for the process innovations than for the product innovations, while the competitive pressure plays a stronger role in the process innovations. These variables play a predominant role in the majority of the situations, as well as other variables (*i.e.* R&D department, Cooperation and Sales) that possess a weaker effect on innovation: Product diversification and cost reduction seem to be the major factors determining the innovative capacity of the firms. In fact, each firm has its specific degree of competitiveness which may not be correctly measured using traditional industrial statistics such as concentration index. We also test more in detail which factors are positively or negatively associated with product or process innovation and these results confirm our conclusions (*see* Appendix, Table 14).

We also remark that the product innovation depends especially on the existence of an R&D department rather than on its size measured by the number of technical workers (*RDForce*). These results, in combination with the role of Cooperation (*see* above, last paragraph of section 4.1, page 9), would suggest that the absorption capacity is the engine of these innovations, more than the internal inventive capacity of the firm. This result appears only in the trees (and not in Table 6) because we have only adopted *depRD* in Probit models since this variable is collinear with $RDforce$. The use of $RDForce$ instead of *depRD* in the Appendix A.5 confirms these findings (table 15). The same phenomenon of collinearity is observed between Export and partForeign: even if these variables play a differentiated role in subsets determined by the regression trees, they are strongly correlated at the global level.

Proposition 2 (Product innovations)
The main determinant of product innovations is demand pull and, more specifically, the need to extend the product range of the firm and to accede to new markets (see Appendix, Table 14). The cooperation with other organisms and the presence of an internal R& D department are also necessary for these innovations. Firms totally owned by foreign capital are very poor product innovators.

Proposition 3 (Process innovations)
The demand pull and the competitive pressure play a complementary role in the development of these innovations, but in a less constraining way in comparison with their role in product innovations. When these two effects are not too weak, and firms are not too small, they have the highest capacity to innovate (see Table 5). When firms are rather small, under the same conditions, foreign owned firms have higher innovative capacity. More specifically, the main motivations for these innovations are (see Appendix, Table 14): improving the product quality; extending the product range and accessing to new markets. The cooperation with other organisms has also a positive impact of this capability.

When we include the variable *sector* in trees, they clearly show that (*see* Figure 6 in Appendix A.2) the capacity to innovate also depends on sectors. In a more general level, the sector to which belongs the firm is an important determinant of its innovative behavior. We show in the following paragraph that it exists a strong heterogeneity between sectors in our data. As a consequence, the last section of the article focuses on the four best represented sectors in our sample.

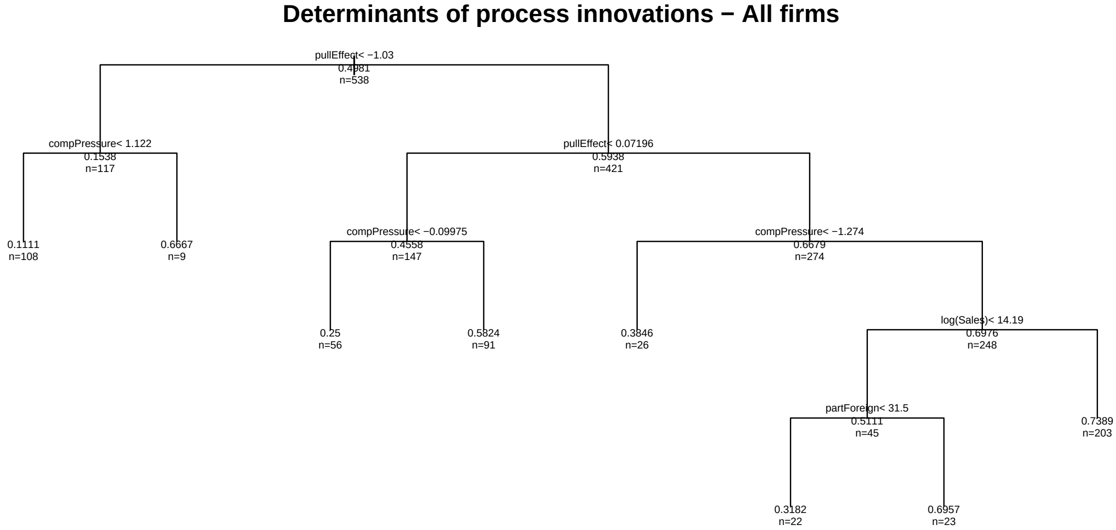


Figure 3: Global determinants of process innovation

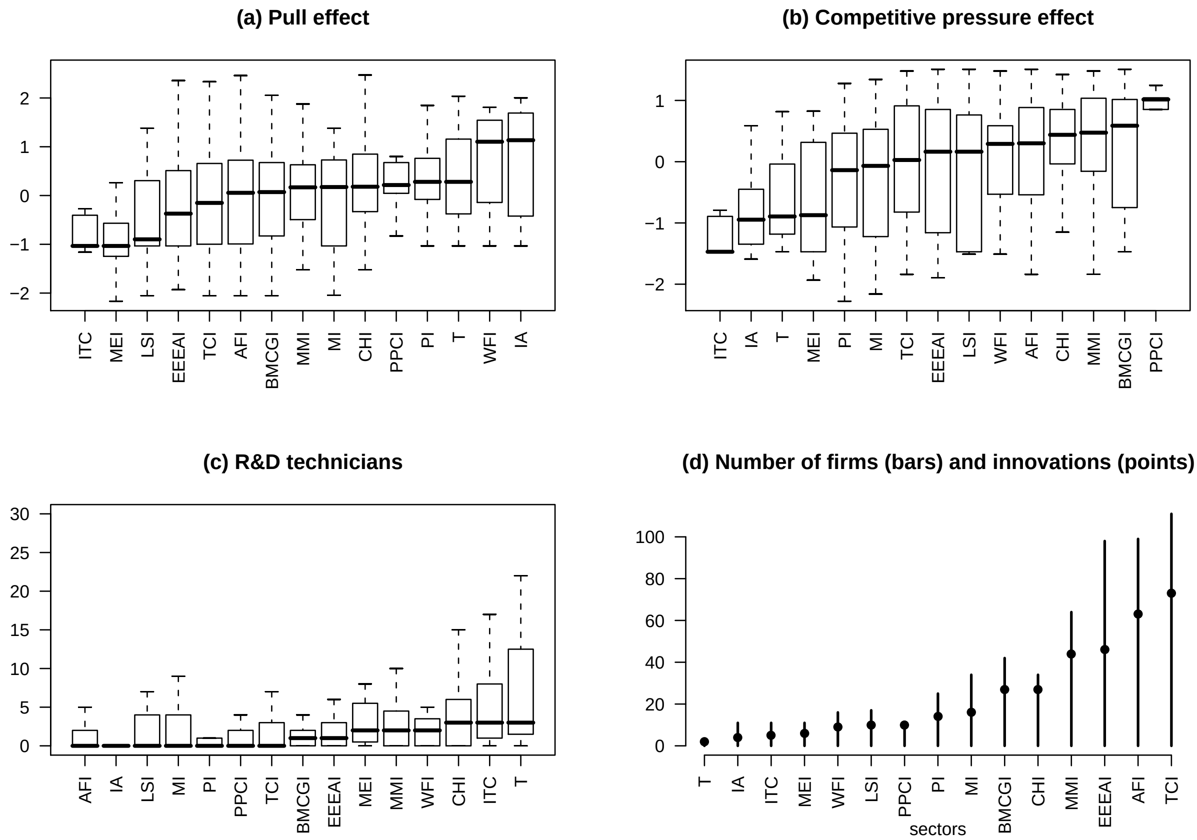
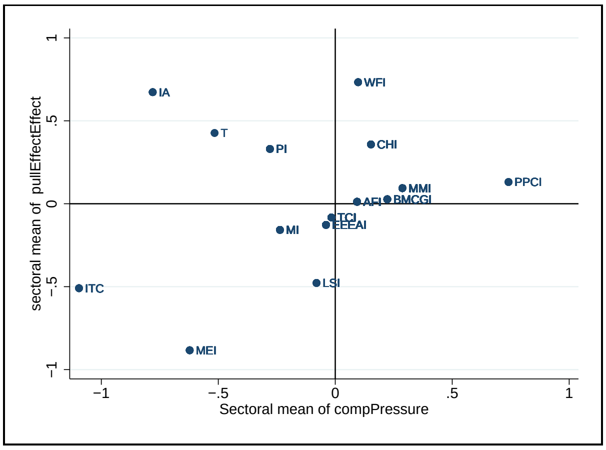


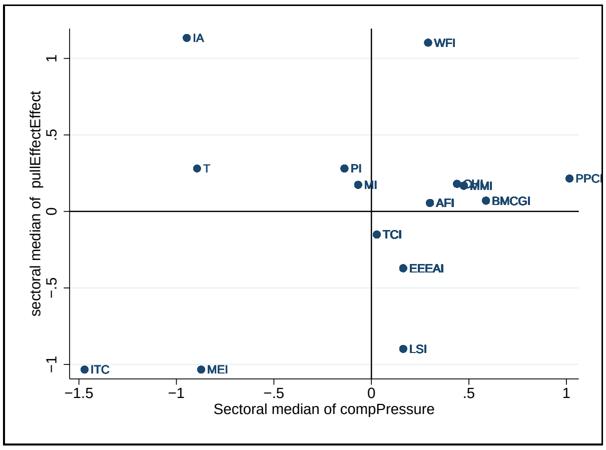
Figure 4: Sectoral patterns of innovation

4.3 Sectoral heterogeneity

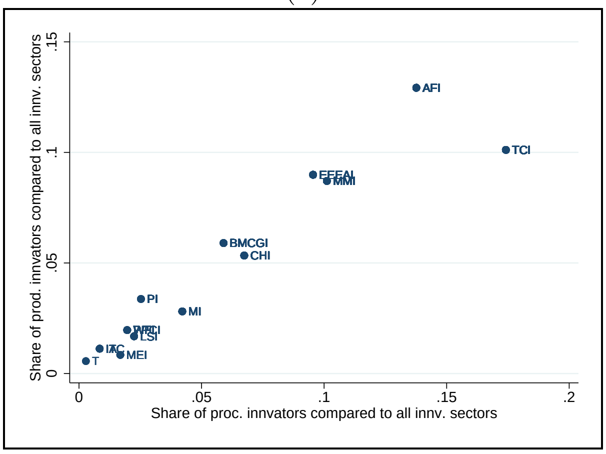
Figure 4 gives the distribution of each corresponding variable in different sectors. Sectors are presented in increasing order in each dimension for the top row (graphics (a) and (b)) and in the increasing innovation numbers for the bottom row (graphics (c) and (d)). We observe that these distributions are quite contrasted between sectors. The strong heterogeneity that exists between sectors is also established in a more systematic way in the Appendix (*see* Section A.6).



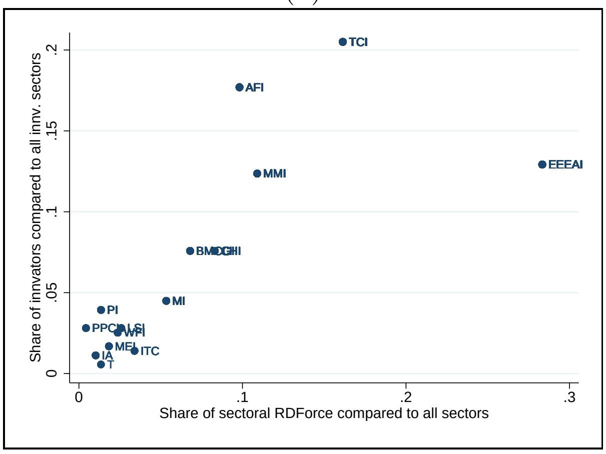
(a)



(b)



(c)



(d)

Figure 5: Positioning of industries based on mean and median of pull and comp. factors and based on the share of innovators compared to all innovators

Figure 5 depicts the differences across all the sectors in the means and median of *pullEffect* and *CompPressure* variables and indicates relative positioning of the industries based on the share of product and process innovators in each sector. Graph 5-(a,b) show that significant heterogeneity exists between sectors concerning the demand pull effect they face, as well as the competitive pressure. Graph 5-(c) shows that the industries with the higher levels of process innovation tend also to have the higher levels of product innovation. The sectors AFI, EEEAI, TCI and MMI have the highest levels of product and process innovation. Graph 5-(d) shows the increasing relationship that exists between the R&D force of the firms and relative innovative capacity of the firms across all sectors. Again the sectors AFI, EEAI, TCI and MMI exhibit superior innovative capacity. We now focus on a closer study and comparison of these sectors. The following proposition summarizes these results.

Proposition 4 (Sectoral heterogeneity)
Significant heterogeneity exists between sectors from the point of view of both structural characteristics

(mainly demand pull and competitive pressure) and innovative behavior. Between sectors, one clearly observes a complementary relationship between innovative capabilities in products and in processes.

Table 8: Median of pull effect and competitive pressure

	Comp. pressure	**Pull**
TCI	0.028	-0.151
AFI	0.300	0.055
EEEAI	0.163	-0.371
MMI	0.474	0.168
All sectors	0.163	0.079

5 Sectoral patterns of innovation: four contrasted sectors

The representativity and the innovation intensity are significantly important in our sample for the following sectors (Table 11 and Table 12 in the Appendix):

TCI: Textiles and clothing industries;

AFI: Agriculture and food industry;

EEEAI: Electrics, electronics and electronic appliances industry;

MMI: Mechanics and metallurgy industry;

These sectors have already been singled out above by their innovative capacity (*see* Graph 5-(c),(d)). Even if they are strongly innovative, these sectors differ on many dimensions: structural characteristics, competitive conditions, strategy and openness (*see* Table 8 and Appendix A.1). Two of them are considerably open to foreign markets (TCI and EEEAI where respectively 79% and 54% of firms are exclusively dedicated to exportation), two of them live under higher competitive pressure and demand pull (AFI and MMI) and two of them have benefited from very strong growth dynamics in recent years (AFI and EEEAI). It is important to verify if some invariant forces are behind their common high innovative capacity or if we are in presence of very differentiated technology dynamics implying industrial and technology policies. Our preliminary results indicate that each sector implements specific strategies to benefit from demand pull and to face competitive pressure.

Table 9: Determinants of maximal expected innovation probability in each sector

Sector	**TCI**		**AFI**		**EEEAI**		**MMI**	
	innovprod	innovproc	innovprod	innovproc	innovprod	innovproc	innovprod	innovproc
max prob	0.9565	0.7778	1	1	0.9167	0.8462	0.7778	1
pullEffect	not weak	strong	not weak	not high	not too weak	not weak	not weak	not weak
compPressure	not weak			not high			not weak	not weak
RDForce					not weak	not weak		not weak
depRD				present				
partForeign								
Export	not low		not high		not high		low	
Sales	not high	not high	not high					not high

As a consequence we now focus on the analysis of these sectors. Regression trees and Probit models allow us investigate the patterns of innovation across these industrial sectors. They give us a comprehensive picture of the sources of product and process innovations.

The regressions trees for these individual sectors are given in Appendix A.3. Major differences between predominant determinants of product and process innovation arise when they are compared across industries. For the sectors AFI, TCI and MMI demand pull influences product innovation more than process innovation, while the inverse is observed for the EEEAI sector (*see* Table 10–(a)) The competitive pressure stimulates mainly process innovations (except for the EEEAI sector where the pull effect is predominant even for process innovations). These results conform with Spence (1975) and Lunn (1986). Because of such patterns, one may expect that firms in specific sectors will use different innovative practices regarding significant factors driving the innovations. For the AFI sector, the effect of $compPressure$ is not significant and the existence of a department of R&D plays a major role in process innovations. Table 9 summaries the most favorable cases in these trees for each sector and for both types of innovation. As in the aggregate analysis, a minimal $pullEffect$ constitutes a general factor favoring innovations but we observe that the factors that yield the highest innovation capability are quite different between sectors and innovation types: As a consequence, we individually study these sectors.

We now rely to the Table 10 and to the individual regression trees (see Appendix A.3) in the analysis of these four sectors. We begin our analysis with two sectors that are particularly main important and strategic for the Tunisian economy: TCI and AFI. The TCI sector is remarkably export oriented and the AFI sector is local market oriented.

Table 10: Sectoral determinants of innovations (marginal impacts)

	Prod. Innov.				Proc.Innov.			
	TCI	EEEAI	AFI	MMI	TCI	EEEAI	AFI	MMI
(a) Sectoral determinants of innovations (marginal impacts)								
PullEffect	0.251**	0.153**	0.249**	0.191*	0.185**	0.175**	0.117†	0.139
compPressure	0.076	0.101†	0.103	0.135	0.217**	0.160**	0.098	0.275**
Department R&D	0.270*	0.197†	0.190	0.152	-0.097	0.089	0.343*	0.390*
Cooperate	-0.036	0.249*	0.217†	0.263†	0.157	0.006	0.115	-0.210
Export	-0.001	-0.002	-0.002	0.001	0.000	-0.001	0.002	0.000
log(Sales)	-0.044	0.027	-0.002	0.019	0.030	0.007	0.049	0.060
Observations	102	87	92	60	102	87	92	60
(b) Predicted probability of innovation								
Reg. tree	0.34	0.33	0.47	0.46	0.58	0.33	0.50	0.58
Probit	0.30	0.25	0.45	0.45	0.58	0.27	0.50	0.58
(c)Decomposition of the pull effect and the competitive pressure (marginal impacts)								
Replace products								
Extend product range	0.272*		0.519**	0.452*				
Sustain market share	0.245*	0.235†						
Access to new markets				0.362*				
Increase production fexibility							0.288*	
Decrease production costs								
Improve product quality		0.359*	0.497*		0.335†			
Improve work conditions						-0.374†		
Increase productivity								
Department R&D	0.272*						0.376*	0.469*
Cooperate		0.332*		0.392*				
Export		-0.002†						
log(Sales)								

Significance levels: $**$: 1% $*$: 5% †: 10%

5.1 Patterns of innovation in the TCI sector

The textiles and clothing industries (TCI) sector in Tunisia is characterized by dynamism for partnership and openness to foreign commerce, and diversity of product lines. The TCI sector exports have increased with an average growth of 48.42% during the past five years. The flexible and differentiated offer and the dynamic evolution of the TCI sector may have created a whole host of opportunities for the innovation process (source: Tunisia's Industry Promotion Agency, 2005). This observation should nevertheless be more nuanced since the liberalization measures of 2005 have implied a strong decrease in this growth: the Table 13 in Appendix A.1 shows that this sector has been shrinking during the recent period. It also is remarkable that the production of more than 79% of the firms is exclusively dedicated to foreign markets. Tunisia has also established two technology parks for ready-to-wear clothes and textiles.

The corresponding trees in the Appendix A.3 show that the TCI sector is characterized by a major role of the demand pull factor for product innovation while competitive pressure plays the predominant role in process innovation. This result is perfectly coherent with the general tendency that we have just observed in the preceding paragraph. The Table 9 shows that for the most favorable case the demand pull is also necessary for all types of innovations. The improvement of product quality plays an important role in the process innovation, while the extension of the product range and the sustaining of market share are important for product innovation (Table 10–(c)). Innovation is hence clearly motivated by the shrinking of the sector and the deterioration of the competitive context. Small firms are more efficient in product innovations, but larger firms can attain comparable effectiveness if they posses an internal R&D lab and if they are motivated by strong competitive pressure. Concerning the predominant role of the competitive pressure in firm's incentives to invest in process innovations, the effects of competition on a firm's process innovations depend on whether a firm exports or benefits from foreign investment, which is determined by the firm's efficiency level relative to that of its opponents. Indeed, the second level branching of the right tree shows that TCI exporting firms have a probability of innovating of 0.9565 if their sales are important and a probability of 0.9091 if *partForeign* is higher than 77%, even if the demand pull effect is weak. Accessing to foreign capital is a non-negligible source for process innovations in this sector. Firm's efficiency level relative to its sales, the existence of R&D department and the size of this R&D department are important determinants of the effect of demand pull on a firm's incentives to undertake product innovation and, then, to extend its product range.

The predicted probabilities given in regression trees and probit model show that the TCI sector is more innovative in process innovations (predicted probability equal to 0.58 for the regression tree and the Probit model) than in product innovations (predicted probability equal to 0.34 for regression tree and 0.30 for Probit).

More specifically, we observe for **process innovations**:

- Competitive pressure and significant access to foreign markets constitute main motivations for innovation.
- Exporting firms under fierce competitive pressure innovate if they are small in size and if the demand pull is not too weak. These innovations are motivated by improving the product quality.
- Small exporting firms under milder demand pull can nevertheless be efficient in innovation if foreign participation is more than 75%.
- Firms fail to introduce process innovations if *pullEffect* and *compPressure* are weak.

The following proposition summarizes these results.

Proposition 5 (Patterns of process innovation in the TCI sector) *Conditions favorable to process innovations are small size, openness to foreign markets and a limited foreign ownership.*

Concerning **product innovations**:

- Firms are likely to be product innovators (introduce new products into the market) if they are small and if the demand pull is important.

- If they are bigger, they can be efficient in innovation if they have a sufficient manpower in R&D.
- The product-oriented effects (product development strategy) is motivated by increasing product range of the firm and sustaining its market share.
- Under low demand pull, an internal R&D force is necessary to assure some innovative capacity.
- Innovative capacity does not depend on foreign exposure of firms (export or participation to capital).

Proposition 6 (Patterns of product innovation in the TCI sector) *Conditions favorable to innovations are small size, internal R&D capacity and demand pull.*

5.2 Patterns of innovation in the AFI sector

Representing 6% of Tunisian GDP, the Agri–Food Industries (AFI) are among the main industrial sectors and this sector occupies the first place among manufacturing sectors in terms of investment. Table 13 in Appendix A.1 shows that the expansion of this sector has accelerated in recent years. The amelioration of quality of life in Tunisia had a definitive positive impact on the internal demand to this sector. But the sector is also quite competitive and to face up to increased competitive pressure, firms need to increase their production flexibilities and improve the quality of their products. Moreover, the production of less than 13% of the firms is exclusively dedicated to foreign markets. These two factors play an important role in process innovations (Table 10–(c)).

Internal R&D (represented by the presence of a laboratory rather than by its size) is an important determinant of innovation in this sector. It is very determinant for product innovations when the demand pull is not very strong and globally strategic for process innovations allowing to fully react to weak demand pull and competitive pressure, especially for small firms (that can attain in this case an expected process innovation probability of 1 – *see* the corresponding regression tree in the Appendix A.3).

We hence observe that the AFI sector has strong investment and innovation potential and the innovation process is R&D based. Indeed, *depRD* plays a predominant role on process innovations unlike any other three sectors where demand pull and competitive pressure are the determinant forces.

Concerning the product innovations, we also observe that not to be mainly dedicated to the foreign markets is also an important driving force when the demand pull is strong and the firms are small. Such firms have a very high capacity to innovate and the expected probability to innovate is 1. As a consequence, addressing the domestic market is not necessarily an impeding factor for innovation, as this is sometime suggested in the literature. But we should not forget that less than 13% of the firms are exclusively export oriented in this sector. More specifically, we observe the following mechanism concerning the **process innovations**:

- Process innovation in the AFI sector is R&D-based. The existence of an internal R&D facility alone assures a probability to innovate close to 50%.
- Firms with R&D department have a very high capacity to innovate when the demand pull and competitive pressure are not important.
- When firms do not have an internal laboratory, they only innovate if the competitive pressure is considerably high.
- The principal aim of process innovation is to increase production flexibility.

Proposition 7 (Patterns of process innovation in the AFI sector) *The innovative capacity of the firm is dramatically dependent on the existence of an internal R&D laboratory. If firms do not benefit from such a facility, they only significantly innovate under strong competitive pressure. Even if this sector is considerably open to foreign markets, exports do not play a determinant role.*

Determinants of **product innovations** are quite different from process innovations:

- Demand pull is the predominant factor for product innovation.
- A very high innovative capacity is observed for small firms that are not completely dedicated to foreign markets and that profit from an important demand pull effect.
- When the demand pull is not very strong, only firms with R&D department have significant innovative capacity.
- Product innovations are mainly motivated by the improvement of product quality and extending the product range, in order to face competitive pressure.

Proposition 8 (Patterns of product innovation in the AFI sector) *A strong demand pull, small size and not to be exclusively dedicated to foreign markets are the necessary conditions for a high innovative capacity.*

We observe that these two important sectors are subject to very different mechanisms concerning their innovative capacity. Openness play a contrasted role. Small size seems to play a rather general role in favoring innovation.

We now consider two relatively smaller but more R&D intensive and growing sectors: EEEAI and MMI.

5.3 Patterns of innovation in the EEEAI sector

Electrics, Electronics and Electrical home Appliance Industry (EEEAI) is an increasingly active sector in Tunisia. The Table 13 in Appendix A.1 shows that this sector has been expanding during the recent period. It is a high performing and a major sector in Tunisia's economy: the EEEAI have been exhibiting remarkable performance, both on the local market (with added value growing by 15% a year) and in the export sector (up to 20% growth on average over the past five years). The production of more than 54% of the firms is exclusively dedicated to foreign markets. The sector also accounts for some 10% of overall jobs in manufacturing industries. The success of Tunisian EEEAI sector is attributable to acquisition of know-how, to the wide range of items produced, to optimized production costs, to strong innovative capacity and to the presence of major international groups (Industry Promotion Agency, 2005).

Table 10–(a) shows a positive effect of competitive pressure and demand pull on product and process innovation. The decomposition of these factors reveals a significant negative effect of the improvement of work conditions on process innovation (Table 10–(c)), showing a potential contradiction between these two objectives. Furthermore, the corresponding regression trees in the Appendix A.3 show a secondary effect of competitive pressure on process innovation. However, the pull effect and the size of the R&D department play important roles in process innovations (the expected probability of innovation is 0.8462 if $pullEffect \geq 0.1693$ and $RDForce > 2$).

The necessity to sustain market share ($pullEffect$) increases the probability of introducing new products into the market. Hence, the incentive for product innovation in the EEEAI sector is the conservation of the market share, and product innovation is used to increase product quality to fulfill this objective (Table 10–(c)).

More specifically, the following observations can be done concerning **process innovations**:

- High process innovation capacity is dependent on strong demand pull and on the presence of an internal R&D force.
- But an intermediate level of innovative capacity is assured when competitive pressure is high enough, independently of other factors.
- When demand pull and competitive pressure are low and firms have a minimal access to foreign markets, their innovative capacity is minimal.

Proposition 9 (Patterns of process innovation in the EEEAI sector) *The main conditions for a high innovative capacity is a high demand pull and the employment of sufficient manpower in R&D.*

The mechanisms behind **product innovations** are quite different:

- Product innovations are motivated by sustaining the market share through product quality increases.
- Pull effect and dedication of enough human resources to R&D and low foreign openness are necessary factors for product innovations.
- Local market oriented firms are more likely to be product innovators ($Export < 39\%$).
- Foreign-market oriented firms can nevertheless have some innovative capacity if they are small.
- At a global level, cooperation with other organisms also favors innovations.

Proposition 10 (Patterns of product innovation in the EEEAI sector) *The main determinant of the innovative capacity is the presence of enough human resources in R&D department. Export is not favorable to innovation.*

5.4 Patterns of innovation in the MMI sector

Fort the Mechanical and Metal Industries (MMI) constitute a relatively small sector since this sector corresponds only to 2% of the GDP in comparison with the 6% corresponding to AFI, or the 5% corresponding to TCI. It is slightly over represented in our sample than in the population. The Table 13 in Appendix A.1 shows that this sector has benefited from significant growth rates during recent years. The production of only 16% of the firms is exclusively dedicated to foreign markets.

Some competitive pressure and some demand pull are necessary for the observation of positive innovative capacity but, in quite a predictable way, the demand pull is the main factor for product innovations while the competitive pressure is predominant for process innovations. The predicted probabilities given by the regression trees and the Probit models show that the MMI is the more innovative sector in processes (more innovative than EEEAI and AFI sectors), with a predicted probability equal to 0.58 in the regression tree and in the Probit model.

Product innovations in the MMI sector obey quite a simple regime: If the competitive pressure is really too low, firms do not innovate at all and, otherwise, firms innovate to face the demand pull.

MMI Firms need to develop new products to accede to new markets and to extend their product range. Cooperation may play an important role for development of new products by exporting firms (Table 10).

The process innovations are also driven by quite a straightforward regime. The innovative capacity is the lowest when the demand pull and the competitive pressure are low. Otherwise, the dedication of some human resources to R&D is necessary in order to attain the highest innovative capacity. Moreover, small firms have a significantly higher capacity in this case.

Concerning **process innovations**, we consequently observe that:

- Competitive pressure is a key factor for introducing new process innovations.

- Firms will be process innovators if the competitive pressure and pull effects are not too weak, and if they dedicate some resources to internal R&D.
- In this case, small firms have higher innovative capacity.

Proposition 11 (Patterns of process innovation in the MMI sector) *A minimal R&D manpower is indispensable to avoid mediocre innovative capacity.*

The process innovation in the MMI sector is technology related. However, the process innovations in the other three sectors are pulled by demand for the EEEAI sector, R&D based for the AFI sector and under competitive pressure for the TCI sector.

Concerning **product innovations**:

- Product innovations mainly pulled by demand, innovations aiming to the extension of product range and to the access to new markets.
- Firms mainly oriented toward the domestic market have the highest innovative capacity.
- Cooperating firms are more innovative in product.

Proposition 12 (Patterns of product innovation in the MMI sector) *Either, a sufficient demand pull and high competitive pressure are necessary for high innovative capacity.*

The specifically important role of cooperation in product innovations in this sector is interesting, especially for exporting firms. Their innovative capacity is dramatically dependent on their capacity to establish these cooperations.

6 Conclusions and policy recommendations

In this first article we analyze industrial characteristics that are favorable to firms in the manufacturing sectors in Tunisia. At the global level, we observe that demand pull, competitive pressure, firm size, as well as internal R&D and cooperation are favorable to innovations. But this global result hides important heterogeneity between types of innovations and sectors. Our first results show that Tunisian firms do not benefit yet from a virtuous national innovation system and firms in each sector develop specific strategies to face demand and competition through innovations.

Globally, firms develop innovative capacity in products (extending the product range, replacing obsolescent products, etc.) mainly for facing the demand, and in processes (reducing production costs, increasing production flexibility,etc.) for responding to the competitive pressure. The existence of internal R&D capacity is in general necessary for product innovations, while cooperation is favorable for both type of innovations. Size of the firms play globally a positive role but the highest innovative capacity corresponds, in many specific cases, to smaller firms. Openness to foreign market also play an ambiguous role: firms principally oriented toward foreign markets tend generally to posses lower innovative capacities. The relation between openness of firms and their innovations is an important question for Tunisian economy and would merit a much extensive study. We plan to develop this point in a following article.

Behind these global results, we observe that sectoral industry and technology policies are indispensable. Indeed, innovations are based on different mechanism between sectors. Our analysis focuses on the detailed analysis of four innovative sectors and we clearly observe that even sectors with partially similar characteristics do not rely on the same mechanisms for developing innovations. For example, internal R&D facilities play an important role in process innovations in all four sectors, but their role is negligible for product innovations in AFI and MMI, while it is preponderant in TCI and EEEAI. Openness to foreign markets is favorable to process innovations in TCI but detrimental for all innovations in other sectors. As a consequence, the supposedly virtuous effect of exports is quite dubious. The role of cooperation is quite invisible except for product innovations in MMI sector. This result is also quite puzzling since more than 30% of firms in all these sectors declare benefiting from some form of cooperation with other organisms. Given that the importance of cooperative agreements in northern countries, this results indicates that their efficiency is yet to be proved in Tunisian sectors. This in fact probably indicate that the correct frameworks for cooperation have not matured yet in the Tunisian system. This deficiency can definitely be corrected by a voluntary industrial policy favoring pre–competitive agreements (like in Japan or in EU). Incentives to form cooperative agreements and to install internal R&D laboratories would be consequently beneficial to innovation in many sectors, especially if these measures aims to small firms serving the domestic market. The last part of this conclusion definitely goes against the orthodox views on industrial policies in the Third world, since these views generally stress the role of exporting firms.

The analysis of this is article has of course several shortcomings. One of them is the focus on the success of innovations. It would be as well interesting to analyze the failures in innovation. Our database can, in some extent allow this and we are working on another article dedicated to this question. A second limitation comes from the rather frustrating proof of the last conclusion on the role of openness. This point definitely deserves a more detailed analysis. We aim to tackle this point in a third article. Of course, as for all survey–based analysis, the formulation of some questions and the absence of historical questions (on the years preceding the survey for example), impedes us from interpreting in a reliable way some answers, and from a dynamic analysis that would of course be very important on a subject as innovative activities. A second survey is being developed for correcting these shortcomings but its results will not be available before 2009. It would be also very interesting to proceed with a comparative analysis with another developing country. We are establishing a partnership with Turkish colleagues to this aims, given the similarities between these two countries.

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A Appendix

A.1 Comparison of the sample and the population (2004)

Population data comes from monographs of manufacturing industries given by the Industry of Promotion Agency in 2005. The Table 11 compares our sample with the population of only the manufacturing firms in Tunisia. It shows that the sectors that we consider in this article are well represented in our sample.

Table 11: Sectoral comparison of the sample with the firm population in 2004

	Population				**Sample**			
Sectors	**TE**	**ATE**	**Total**	**Part(%)**	**TE**	**ATE**	**Total**	**Part(%)**
AFI	121	824	945	17%	23	67	90	17%
BMCGI	19	409	428	8%	3	37	40	8%
MMI	78	403	481	9%	13	50	63	12%
EEEAI	153	130	283	5%	66	30	96	18%
CHI (Other plastics)	31	218	249	5%	2	32	34	6%
TCI	1656	438	2094	38%	75	35	110	21%
LSI	178	111	289	5%	12	4	16	3%
WFI	31	174	205	4%	1	15	16	3%
MI**	93	401	494	9%	17	47	64	12%
Total	**2360**	**3108**	**5468**	**100%**	**212**	**317**	**529**	**100%**

TE : Totally Exporting
ATE : Other than Totally Exporting
****** To compare our sample with the population of manufacturing firms we supposed that miscellaneous industry (MI) regroup here the pulp, paper and cardboard industry (PPCI), mine and energy (MEI), the plastic industry (PI) and others.

The Table 12 gives the distribution of the firms between the four sectors that we study and their corresponding characteristics. It is remarkable that the firms' number in table 11 does not correspond to this one in table 12. Indeed, in the first one we keep only sectors that reply that their activities are not "services".

Table 12: Distribution of firms of the four sectors

	Firms' nber	**innov. prod.**	**innov. proc.**	**depRD**	**Cooperative**	**Exporting**
AFI	**99**	46	49	45	46	61
	16.89%	46.46%	49.49 %	45.45%	46.46%	61.62%
EEEAI	**98**	32	34	52	30	85
	16.72%	32.65%	34.69%	53.06%	30.61%	86.73%
TCI	**111**	36	62	53	40	95
	18.94%	32.43%	55.86%	47.75%	36.04%	85.59%
MMI	**64**	31	36	44	28	48
	10.92%	48.44 %	56.25%	68.75%	43.75%	75.00%
All	**586**	**240**	**285**	**316**	**239**	**429**
	100%	**40.96%**	**48.63%**	**53.92%**	**40.78%**	**73.21%**

Table 13 displays growth rates of different sectors in the period preceding the survey.

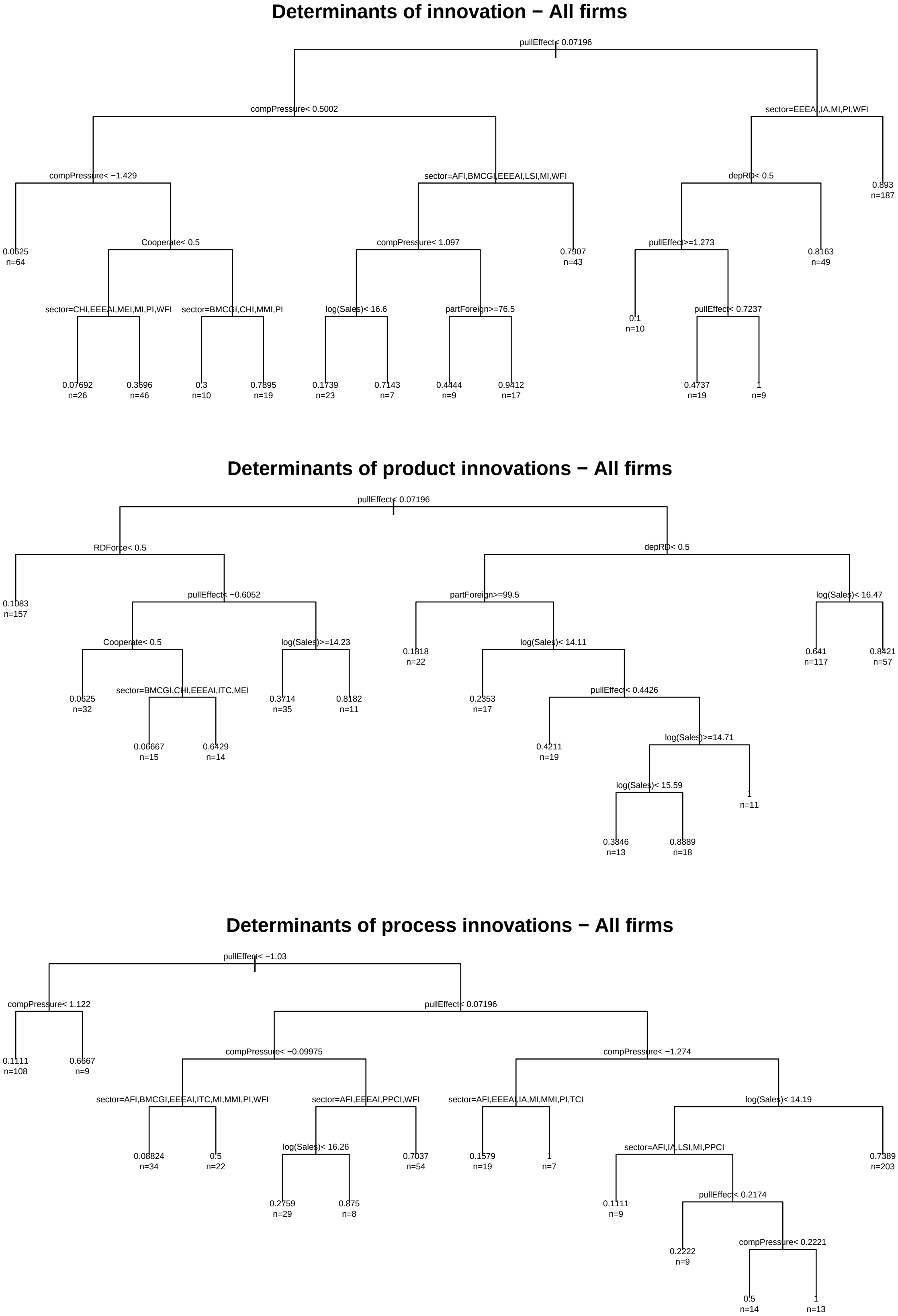


Figure 6: Global determinants of innovation (including sectors)

Table 13: Production trends in manufacturing industries

Sectors	1997-1999	1999-2001	2001-2004
AFI	16%	12%	30%
BMCGI	16%	15%	23%
MMI	17%	16%	19%
EEEAI	28%	40%	39%
CHI	17%	0%	15%
TCI	22%	21%	-2%
LSI	22%	15%	48%
WFI	22%	17%	22%
MI	18%	14%	11%
Total	**19%**	**15%**	**18%**

The authors from Monographs of manufacturing industries

A.2 Global trees with *sector*

A.3 Sectoral trees

Detailed results for each sector is given in the regression trees in the Figure 7.

A.4 Desegregating the pull effect and competitive pressure

Table 14 gives Probit results when we consider individual effects that compose the factors $PullEffect$ and $compPressure$.

Table 14: Disaggregating the pull effect and competitive pressure

	Prod. Innov.		Proc. Innov.	
	Coeff.	Marginal	Coeff	Marginal
Replace products				
Extend product range	0.839**	0.302**	0.455**	0.179**
Sustain market share	0.270†	0.100†		
Access to new markets	0.338*	0.125*	0.427**	0.168**
Increase production fexibility	-0.251†	-0.093†		
Decrease production costs				
Improve product quality	0.527**	0.188**	0.822**	0.311**
Improve work conditions				
Increase productivity				
Department R&D	0.469**	0.174**		
Cooperate	0.281*	0.106*	0.258*	0.103*
Export				
log(Sales)	0.065†	0.024†	0.105**	0.042**
Constant	-2.788**		-3.095**	

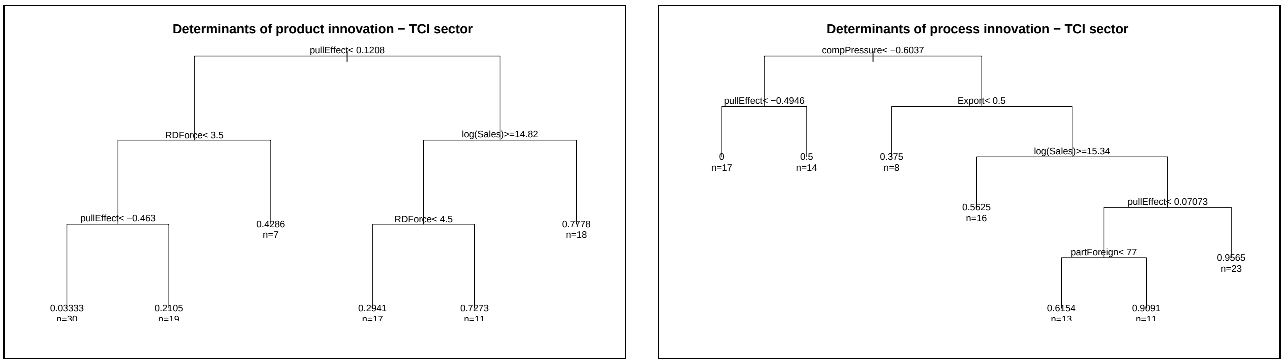
Significance levels: $**$: 1% $*$: 5% † : 10%

A.5 Probit regressions using $RDForce$ instead of $depRD$

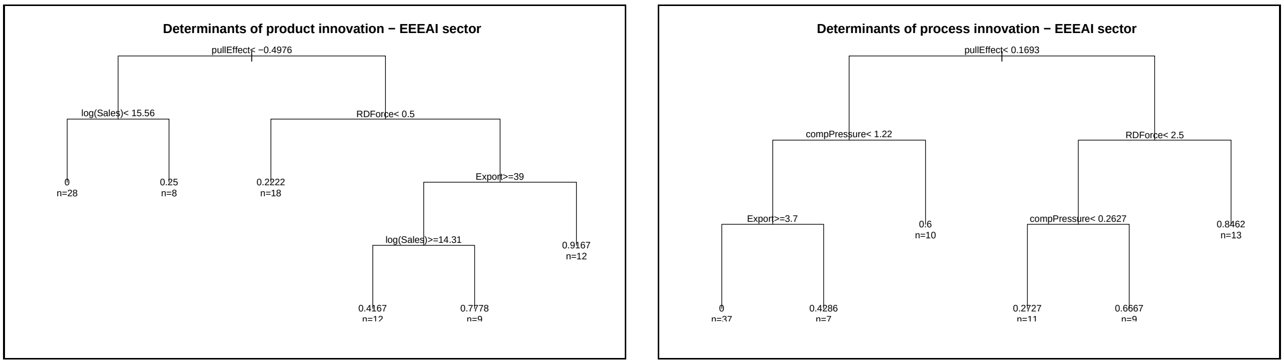
Results are given in Table 15

A.6 Duncan's test for heterogeneity of the sectors

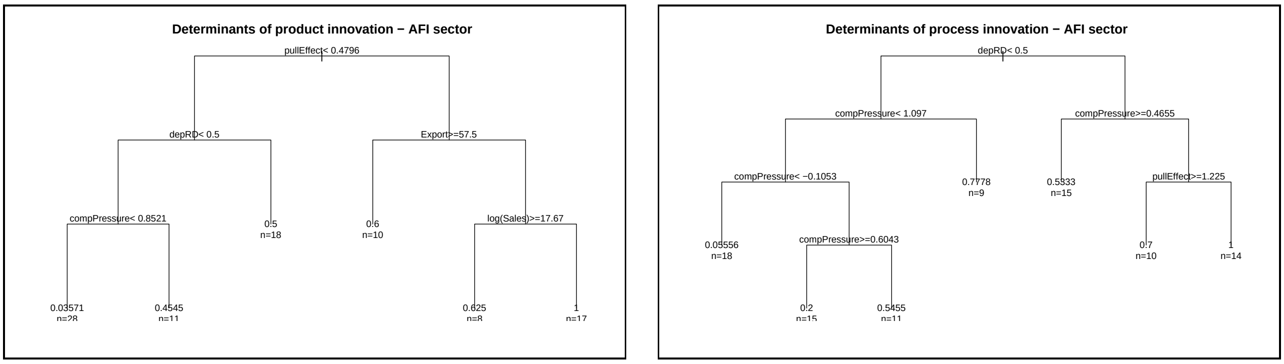
For testing the homogeneity hypothesis that all sectoral means of variables *pullEffect*, *compPressure* and *RDForce* are equal, we also applied Duncan's multiple range test after the procedure one-way analysis of the variance (Duncan 1955). We performed a one-way analysis of variance for each variable. We constructed various tests and graphs to compare the mean values of them for the different sectors. Table 16 reports which means are significantly different from which others for the all sectors at the 95% confidence level. The P-value and the F-ratio, which is a ratio of the between-group estimate to the within-group estimate, show there is a statistically significant difference between



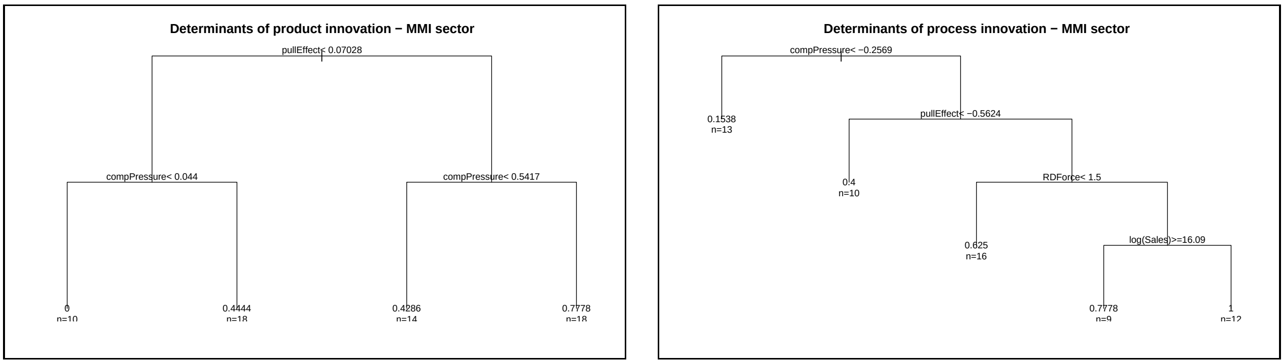
Determinants of innovations in the TCI sector



Determinants of innovations in the EEAI sector



Determinants of innovations in the AFI sector



Determinants of innovations in the MMI sector

Figure 7: Regression trees for the analyzed sectors

Table 15: Probit regressions: global determinants of innovations

	All innov.		Prod. Innov.		Proc. Innov.	
	Coeff.	Marginal	Coeff.	Marginal	Coeff	Marginal
pullEffect	0.618***	0.228***	0.573***	0.219***	0.426***	0.170***
	(0.069)	(0.025)	(0.065)	(0.025)	(0.062)	(0.025)
compPressure	0.462***	0.170***	0.282***	0.108***	0.421***	0.168***
	(0.065)	(0.024)	(0.064)	(0.024)	(0.062)	(0.025)
RDForce	0.033*	0.012*	0.015	0.006	**0.028***	**0.011***
	(0.015)	(0.006)	(0.011)	(0.004)	(0.013)	(0.005)
Cooperate	0.530***	0.190***	0.398**	0.152**	0.304*	0.121*
	(0.136)	(0.047)	(0.125)	(0.047)	(0.124)	(0.049)
Export	-0.001	-0.000	-0.002	-0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
lnSales	0.112**	0.041**	0.075*	0.029*	0.098**	0.039**
	(0.039)	(0.015)	(0.038)	(0.014)	(0.037)	(0.015)
cons	-1.617**		-1.555**		-1.764**	
	(0.612)		(0.592)		(0.584)	

Significance levels: $***$: 0.1% $**$: 1% $*$: 5%

the means *pullEffect* and *compPressure* from one sector to another at the 95% confidence level. The Multiple Range Tests applied a multiple comparison procedure to determine which means are significantly different from which others. However, the difference may be caused by the presence of outliers. Thus, we choose the Kruskal-Wallis Test which compares medians instead of means. The various plots help us judge the practical significance of the results, as well as allow us to look for possible violations of the assumptions underlying the analysis of variance. The Kruskal-Wallis test tests the null hypothesis that the medians of variables within each sector are the same. The data from all sectors is first combined and ranked from smallest to largest. The average rank is then computed for each sector. Since the P-value is less than 0.05, there is a statistically significant difference among the medians at the 95% confidence level.

Table 16: ANOVA and Duncan tests of means of variables in different sectors

	pullEffect	compPressure	RDForce	Innovprod	Innovproc
F-Ratio	**3.03**	**3.30**	**0.99**	**1.55**	**1,92**
P-Value	**0.0002**	**0.0000**	**0.4629**	**0.0898**	**0,0219**
Duncan test :					
significant differences in means of sectoral groups	AI vs. (LSI,MEI,ITC) AFI vs. MEI WFI vs. (LSI,EEEAI, MEI,ITC,others) LSI vs. (CHI,T) CHI vs. (MEI,ITC) PCI vs. (MEI, ITC) BMCGI vs. MEI MEI vs. (MMI,PPCI, TCI,T) T vs. ITC	AI vs. (AFI,WFI, BMCGI,MMI,PPCI) AFI vs. ITC WFI vs. ITC LSI vs. (PPCI,ITC) CHI vs. ITC PCI vs. (PPCI,ITC) EEEAI vs. ITC BMCGI vs. (MEI,ITC) MEI vs. (MMI,PPCI ,ITC) PPCI vs. (T,ITC) TCI vs. ITC	None	None	None
Kruskal-Wallis Test					
Test statistic	**38.528**	**42.802**	**34.994**	**32.146**	**26.327**
P-Value	**0.0004**	**0.00009**	**0.00147**	**0.0038**	**0.0235**

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