

ARTICLE PROPOSÉ POUR

Le 2^{ème} colloque du GDRI DREEM organisé dans le cadre de l'Année
franco-égyptienne de la science et de la technologie

Le Caire, Egypte
13-14 décembre 2010
Hôtel Mariott
Université du Caire et CEDEJ

INNOVATION AND R&D INVESTMENT OF TUNISIAN FIRMS: A TWO- REGIME MODEL WITH SELECTIVITY CORRECTION

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Abstract

The purpose of this paper is to produce new empirical evidence on the determinants of Tunisian firms R&D investment, by considering the effect of innovation probability of firms on R&D investment. We estimate econometric models of selectivity correction (Heckman 1976 and 1979; Lee 1976 and 1978) and consider a sample of 321 firms during the period 2002-2005. On the one hand, the results show the positive impact of R&D activities, human capital quality, past experience in innovation and public subsidies on probability of firms to innovate whereas ownership structure have a negative impact. On the other hand, we estimate the determinants of R&D expenditure for the two groups of firms (innovating and non-innovating). There are spillover effects only for innovating firms which have an absorptive capacity. Finally, ownership structure has a significant impact on R&D investment especially for foreign controlled firms.

Keys words: Innovation, R&D, Spillover, Absorptive Capacity, Selectivity Correction

JEL Classification: D21, O31, O32

I. Introduction

Innovation and R&D activities are important factors of competitiveness at both firm and national level. Despite constant academic efforts and a growing literature on the relationship between R&D activity and innovation, our empirical knowledge of the motives and the impacts of R&D investment remain rather limited for developing countries, and more precisely for Tunisia. Because of the gradual trade liberalization pursued by Tunisia (accession to GATT agreements and free trade association with the European Union in 1995), Tunisian companies had to enhance their competitiveness. Firms competing in global markets face the challenges and the opportunities of the convergence of consumer preferences and the scope of technological change, engaging them in extensive and risky sunk R&D expenditures.

For developing countries, such as Tunisia, innovation activity seems to be rather an adoption of foreign technologies which requires more adaptation effort to the domestic context. If we consider product innovation, this means “products new to the firm” rather than “products new to the relevant market”. The first category of innovation, most common in developing countries such as Tunisia, appears as imitative strategy (when taking the world market as a reference point) whereas the second means radical innovation strategy (generally observed in developed countries). Thus, R&D expenditures in developing countries depend on firm’s innovation strategy, i.e., innovating or non-innovating. This means that firms invest in R&D either to adapt foreign technologies to the Tunisian market or to enhance their competitiveness when facing a greater foreign competition without innovating. We should also note that in such context R&D activities are not well structured (with independent cell and full-time R&D personnel) and could be implicit activity. For instance, firms could consider that they don’t have R&D activities since they are not innovating whereas they are expending on R&D.

The relationship between R&D activity and firm's performance is far from being a recent field of research, as shown among others in surveys by Mohnen (1996), Griliches (1995) or Mairesse and Sassenou (1991). It is now well-known that, besides the impact of a firm own R&D expenses, positive externalities stem from other firms’ R&D activity, i.e., there are diffusion or spillover effects. However firms cannot benefit from this technological spillover unless they have absorptive capacity (Cohen and Levinthal, 1989). So firms invest in their own R&D to be able to utilize the technological knowledge which is externally available. Accordingly, we argue that while R&D obviously generates innovations, it also develops the firm's ability to identify, assimilate, and exploit knowledge from the environment. Some empirical analyses have tested this double effect of R&D in the case of U.S companies (Arora and Gambardella, 1994), German enterprises (Fritsch and Lukas, 2001), Spanish firms (Del Canto and Gonzalez, 1999), Flemish companies (Veugelers, 1997) and French firms (Paul et al., 2000; Negassi, 2004). However, empirical analyses at the firm level in the case of developing countries remain rather limited.

The main object of this paper is to report new empirical evidence on firm's incentive to invest in R&D according to whether the firm is innovating or not. Survey data on R&D

activities and innovation of Tunisian firms (carried out by the Ministry of Scientific Research and Competences' Development in 2005) is used to investigate determinants of R&D expenditure and innovation. More precisely, the purpose of this paper is to produce new empirical evidence on the determinants of R&D investment, while introducing the relationship between R&D expenditure and innovation effort of firms. We suggest that Tunisian firms invest in R&D not only to innovate, but also to enhance their ability to assimilate and exploit existing technological knowledge (from other firms' R&D activity). Thus, we can expect that R&D investment will be explained by absorptive capacity.

Our ambition in this paper is twofold. Firstly, the determinants of innovation for Tunisian firms are highlighted. Furthermore, the most frequent factors like size, group membership, ownership structure, human qualification and past experience in innovation activities are investigated (Cohen and Levin, 1989; Freeman, 1990; Kleinknecht and Mohnen, 2001; Negassi, 2004). However, innovation activities have only become of significant interest for Tunisian manufacturing firms in the last two decades. Indeed, in order to help Tunisian companies to face foreign competition¹, public authorities put forward in 1996 an industrial upgrading program, called "*Mise à Niveau*". The goal of the program was to improve the competitiveness of Tunisian industry, particularly in export markets. Launched on a pilot scale in 1996, the program, supported in part by EU grants, has consisted of technical assistance, training, subsidies, and infrastructure upgrades aimed at encouraging and assisting Tunisian private sector restructuring and modernization. Subsequently, in this paper, we examine the effect of public subsidies in relation to this program on innovation activity of firms.

Secondly, R&D expenditure of Tunisian firms has increased in recent years. Determinants of firm's R&D investment are investigated according to whether the firm is innovating or not. Incentives to invest in R&D are not the same for the two kinds of firms. There is a closer relationship between R&D and innovation activities. Innovating firms invest in R&D activity to introduce new product or process whereas non-innovating enterprises invest in R&D activity to enhance their absorptive capacity². Thus, besides the usual determinants of internal R&D expenditures (such as size, market share, collaboration, etc...) we consider the effect of technological spillover.

There is a large debate on the complementarities/substitutions of internal and external R&D. Although the availability of external technology may discourage – and hence substitute

¹ The globalization process began in Tunisia in the 1970s, but significant measures of liberalization of trade and capital inflows were introduced in the middle of the 1990s, in particular with the membership of Tunisia to the WTO and the signing in 1995 of the free trade agreement between Tunisia and European Union.

² More clearly this doesn't mean that there is one type of R&D increasing likelihood of innovation, and another type as increasing absorptive capacity (and not the ability to innovate), but we suggest that determinants of R&D are different according to whether the firm is innovating or not. Thus, studying the issue of causality between innovation and R&D investment is not considered here.

for – own research investment by the receiver firms, there are also arguments to stress the complementarities between in-house R&D and external know-how (Veugelers, 1997).

Own in-house R&D allows modifying and improving external acquisition (Cohen and Levinthal, 1989) via learning about foreign equipments or goods (Grossman and Helpman, 1995), buying patents (Jaffe, 1986), using new materials, relationships with foreign firms (Blomström and Kokko, 2003), etc... However, there are also several reasons (costs, risks, competences, time, etc...) which claim for substitutability between internal and external R&D.

The relationship between R&D expenditure and the likelihood of Tunisian firms to innovate provides some insights about innovation policy for public authorities. In order to help non-innovating firms to enhance their competitiveness, it is meaningful to apply a system's competence in an economy characterized by rapid change. A competence system is based on a number of rules, legislations, institutions, types of funding, location choices, actors' networks and educational and training programs. In short, a competence system is based on a set of components so related or connected as to form a whole lot of arrangement which enables firms to better benefit from external knowledge and to innovate. Even if firms are non-innovating, it is essential do develop their own system of competences to improve their competitiveness. This paper highlights the components of such a system as well as its limits.

The rest of the paper is organized as follows: Section 2 presents the switching model to be estimated. Section 3 describes the sample of firms and the measures of variables. Section 4 presents and analyzes the econometric results. Finally, section 5 concludes the paper and provides some recommendations and policy implications.

II. Econometric specification of the model

The model we estimate considers the link between R&D investments and innovation activity of firms. The determinants of R&D expenditure for an individual firm are not independent of its probability to be innovating or non-innovating. Factors explaining in-house R&D are not the same according to whether the firm is innovating or not. So, there is a problem of selectivity in estimating determinants of R&D investment according to the innovating/non-innovating position of firm³.

Our empirical analysis uses econometric models of selectivity correction. More precisely, the analysis presents a direct adaptation of Heckman's model (1976 and 1979) combined with Lee's development (1976 and 1978). This two-regime model corrects the selectivity problem in estimating qualitative (estimation of the probability to innovate) and quantitative (estimation of the R&D investment function according to innovation regime) parts of the model. The model supposes two stages.

³ Innovation can be considered as an auto-selection process. Expected R&D investment is subject to innovation status and thus selectivity problem considered here is more complex than a sample selectivity bias. It is then necessary to limit the observed heterogeneity between firms and to control non observed heterogeneity.

Firstly, we consider the determinants of product innovation⁴. Unlike most of the previous studies on innovation, we do not measure innovation through R&D investment, patents or the number of marketed innovations. There are several well-known limitations of these measurements (see Griliches, 1990 or Patel and Pavitt, 1993). However, we use a qualitative measure, i.e., the variable takes the value 1 if the firm innovates, 0 otherwise. We estimate thus probit model to explain the probability of firm to innovate. These estimations will be realized for all firms in the sample, distinguishing between two innovation situations:

$$j = 1 \text{ if firm innovates}$$

$$j = 0 \text{ if firm doesn't innovate}$$

In order to verify if R&D investments function depends on innovation situation of firms, it is important to consider selection mechanism in relation to innovation conditions when estimating the determinants of R&D investment. Thus, the first part of the model explicitly represents the selection process.

Secondly, we estimate determinants of firm's R&D investment according to whether the firm is innovating or not. Incentives to invest in R&D are not the same for the two kinds of firms. Innovating firms invest in R&D activity to carry out new products whereas non-innovating enterprises invest in R&D activity to enhance their absorptive capacity. Thus, we consider the effect of technological spillover on R&D expenditure. The first stage results will be utilized in estimating R&D investment function (two equations will be considered according to innovation situation of firm). This method is interesting because it enables us to isolate specific effects of independents variables, and more precisely of the real effect of an innovation regime on R&D investment.

Determinants of innovation are related both to own characteristics of firms (size, membership of group, skills, sectoral specificities, etc.) and to market conditions (spillover, subsidies, opportunities, etc...). Formally, the innovation may occur as the result of the following process decision. The firm faces a large set of expected sales of the innovative output (δ) and have costs of production related to innovation (c). The expected profit of the firm in relation to innovation ($y^* = \delta - c$) depends on different factors, such as firm characteristics, market structure or sectoral specificities. Even though the costs of innovations may be evaluated, the returns of innovations are difficult to identify and measure especially if they occur in the various possible areas, if they are incremental and if they yield returns in the long run. This is why the expected profit is considered here; as the latent variable. If we consider the innovation decision as a dichotomous variable, the decision rule can be defined as:

$$I = 1 \text{ if the firm innovates } (y^* > 0)$$

⁴ We focus our analysis only on product innovation because the relationship between R&D investment and innovation activities is more meaningful for product innovations than for process ones. Product innovation is defined in relation to the firm as the implementation of a new or significantly improved product.

$I = 0$ if the firm doesn't innovate ($y^* < 0$)

Thus, the econometric model we estimate can be presented as follows:

$$\begin{cases} I_i = X_i' \beta + \mu_i & (1) \\ \ln(RD)_{ij} = W_{ij}' \alpha_j + \gamma' \hat{\lambda}_{ij} + \varepsilon_{ij} & ; j = 0, 1 & (2) \end{cases}$$

Where variables and parameters are defined as follows:

I_i is a dichotomous variable which takes the value 1 if the firm innovates, 0 otherwise ($i = 1, \dots, N$).

X_i and W_{ij} are vectors of explanatory variables (see below for description of independents variables).

$\ln(RD)_{ij}$ is the log of R&D expenditures of firm i in situation j .

α, β and γ are the estimated parameters.

$\hat{\lambda}_{ij}$ are ratios of Mills (correctors terms of selectivity): $\hat{\lambda}_{i1} = \frac{\phi(X_{ij}' \hat{\beta})}{\Phi(X_{ij}' \hat{\beta})}$ if $I_i = 1$ and

$$\hat{\lambda}_{i0} = \frac{-\phi(X_{ij}' \hat{\beta})}{1 - \Phi(X_{ij}' \hat{\beta})} \text{ if } I_i = 0.$$

$\phi(\cdot)$ and $\Phi(\cdot)$ are respectively normal density and distribution function.

μ_{ij} and ε_{ij} are random error terms.

Estimation of equation (1) of the model identifies determinants of innovation. Equation (2) truly represents two equations related to R&D investment. This econometric model supposes the estimation of qualitative structure at the first stage in order to calculate corrector's terms of selectivity $\hat{\lambda}_{ij}$.

III. Description of Data and measures of independent variables

In this paper, we use the survey data provided by the Ministry of Scientific Research and Competences' Development⁵. The survey was conducted during the period 2002-2005 and the sample size is of 321 firms (all manufacturing activities were considered).

Manufacturing firms, all with at least 10 employees, answer questions primarily concerned with R&D activities and expenditure, innovation projects (products, process, abandoned, unfinished), objectives of innovation, obstacles to innovation, principal activities of in-house R&D, and, finally, public incentives to R&D and innovation activities. Among

⁵ *Ministère de la Recherche Scientifique et du Développement des Compétences en Tunisie.*

the 321 firms that responded to the survey, 60.7% declared having R&D activities⁶, 20.2% of them occasionally and 40.5% continuously. The highest levels of R&D expenditures are in electric and electronic industries and in chemical industries. The distribution of firms according to their activities is shown in Table 1 below. Column 2 of this table gives the percentage of innovating firms in each sector.

Table 1: Distribution of innovating firms according to branch activities

<i>Activities</i>	<i>% of firms</i>	<i>% of innovative firms</i>
Mechanical and Metallurgical industries	13.1	73.8
Food	16.2	75.0
Textile and Clothing	17.1	60.0
Paste, Paper, Cardboard	2.2	85.7
Leather and shoes	3.1	50.0
Wood	2.8	88.9
Electric, Electronic and household equipment	15.6	60.0
Rubber and plastic	3.7	58.3
Mine and Energy	2.2	57.1
Construction materials, Ceramic and Glass	7.8	60.0
Chemicals	7.5	91.7
Informatics	2.2	85.7
Transport	0.6	50.0
Communication and information technology	1.2	75.0
Others	4.7	66.7

Regarding the innovation effort of Tunisian firms, 70% are innovating⁷. We note that 51% of firms have at least one product innovation, 49% have at least one process innovation, and 34% have at least abandoned or unfinished innovation. Regarding the sectoral distribution of firms, the most innovative industries are Farm – Produce industry (19%), Electric, Electronic and Electro mechanic industries (13%) and finally Mechanics, Metallic and Metallurgic industries (12%).

⁶ These percentages are derived from responses of firms to a qualitative question (“are you doing R&D activities between 2002 and 2005?”). If the firm responds by “yes”, then she should precise if these activities are done in a *continuously* or *occasionally* way). Thus, these percentages don’t mean that 39.3% of observations would be missing values when estimating the determinant of R&D investment. These firms are investing in R&D as some rubrics show expenditures of firms in R&D (mainly as investment not directly related to innovation activities such as personal training, purchase of patents, etc.) while they are declaring that they are not doing R&D.

⁷ The drawback of using data coming from survey on innovation is the subjectivity of respondents and the too large number of firms declaring innovating. On the other hand, limits of using quantitative information on firm behavior with respect to innovation (such as R&D investment and patents) are also well-known in the empirical literature on innovation. No all innovating firms invest in R&D and even less patent their inventions. In the case of developing countries such as Tunisia, we should remember that innovation seems to be rather an adoption of foreign technologies than a truly innovation for the relevant market as in developed countries. This explains the high percentage of innovating firms in Tunisia (70%).

We consider R&D investment and innovation to be function of industry and firm characteristics. There are three sets of independent variables.

III.1. Independent variables common to equations (1) and (2)

III.1.1. Size

Firm size is measured by the turnover (*size*). The link between innovation and firm size has been thoroughly examined in many papers, dating back to Schumpeter's work on firm size and market concentration. Large firms are considered to be relatively more innovative than smaller ones, but the latter seem to be more productive in radical innovation (see Cohen, 1996, for a survey of these works). Economies of scale in R&D, the ability to spread risks over a portfolio of projects and access to a larger pool of financial means, give large firms an advantage over smaller firms in investing in R&D. However, flexibility, adaptability and efficient internal communication allow smaller companies to be quicker in responding to external opportunities and changes. Empirical results diverge on the impact of firm size. Examining the effect of firm size on internal R&D, Veugelers (1997) found a positive impact. However, Acs and Audretsch (1987) showed that, although small and medium sized firms spend less on R&D than larger firms in aggregate, they produce almost twice as many innovations on a "per employee" basis⁸. Smaller size may have positive effects on R&D activities such as better networks of communication and co-ordination, informal controls, etc...

III.1.2. Group membership

Group is a dummy variable which takes the value 1 if the firm belongs to a group, 0 otherwise. When the firm is a member of a group, it has an advantage in access to R&D performed by other firms of the group and then has a higher probability of being innovating (Paul *et al.*, 2000). Also, firms belonging to a group have better information on market opportunities. However, firms that are part of groups should invest in their own R&D to enhance their absorptive capacity.

III.1.3. Ownership structure

If R&D remains a centralized function within a multinational firm, the R&D strategy of subsidiary companies in host economies may be seriously affected positively or negatively by the parent company. In the same way, if the firm is state-controlled, innovation and R&D strategies may be influenced negatively or positively. The presence of public authorities in firm's capital can be either source of complexity and loss of flexibility or a source of greater market power. To investigate the effect of capital structure of a firm on its R&D expenditure and innovation activities, we consider two measures. The first denotes the share of foreign capital (*Foreign Capital*) and the second is the percentage of government capital participation (*Public Capital*).

⁸ As noted by Kleinknecht, Van Monfort and Brower (2001), it should be mentioned that the data used by Acs and Audretsch (1987) is strongly biased towards under-estimation of innovation in larger firms.

III.1.4. Human capital

Availability of a team of scientists and technicians with suitable qualifications and know-how in R&D activities are required resources for innovation. This human capital injects higher skills and knowledge into the organization, which is positive for the realization of R&D activities. Including a measurement of human capital in our regressions is necessary to account for the skills embodied in the employees themselves. Our human capital measurement (*Human capital*) is the number of qualified labor, i.e., number of technicians and engineers/administrators in R&D activities divided by the total number of employees. We consider also a qualitative measure of employees' skills (*skills*) which is the importance (on *likert's* five point scale) that firm gives to personnel qualification.

III.2. Independent variables specific to equation (1)

The determinants of innovation include variables related to firms' characteristics.

III.2.1. R&D activities

It is well known that R&D investment can simply be seen as an important input to innovative activities. We cannot use R&D expenditures as a measure of R&D activities in firms because this measure will be used in equation (2). So we consider a dummy variable (*R&D-activities*) that takes on the value of 1 if the firm makes any R&D activities, 0 otherwise. About 34% of the sample companies have a staffed R&D department. This percentage is considerably higher for large companies and high-tech sectors indicating economies of scale.

III.2.2. Experience in innovation

Firms which have unfinished innovation projects are potentially innovating ones. They can be viewed as knowledge-based organizations. Firms which launch a project of innovation have certainly acquired technical knowledge, integrated skilled work force and developed adequate organization. So even if companies are not innovating, the experience in innovation project enables firms to improve their probability to innovate. We used a dummy variable (*Experience-innovation*) that takes on the value of 1 if the firms has unfinished projects of innovation, 0 otherwise.

III.2.3. Public subsidies

Innovative activities often benefit from the support of government agencies through several grant and subsidization mechanisms (for a survey, see Pavitt, 1976). In the survey data, firms have to indicate if they have acquired any forms of public subsidies in the past five years⁹. Thus, we constructed a synthesised variable (*public subsidies*) which takes the value of 1 if the firm responds positively for at least one form of subsidies, 0 otherwise.

⁹ Public incentives to R&D and innovation in Tunisia take several forms: Priority technological investment (ITP), R&D investment subsidy (PIRD), Program of research results valorisation (VRR), National program of research and innovation (PNRI), Incentive regime to innovation in the field of information technology (RITI), Program of researcher's mobility (*Mobilité*)

Many empirical studies have tried to estimate the efficiency of R&D subsidies and have generally concluded that privately-funded R&D in manufacturing industries yields a higher rate of return than R&D performed with government funding (for a survey, see Griliches, 1995). Indeed, these subsidies often target areas where there is a wide gap between the social and the private rate return (Negassi, 2004). In this case, it is unlikely that R&D subsidies are a substitute for private R&D investment. In fact, these grants give firms an absorptive capacity which can be then used to acquire external knowledge or to generate new products/process, i.e., increasing the productivity of a firm's R&D. On the other hand, there is a possibility that such subsidies will be utilized in projects with high private rates of return, either to ensure the appearance of a successful public policy, or because governments can lobby firms for the projects they favour. Therefore, in this case, it is likely that government grants may be a substitute rather than a complement to private R&D investment. So, the effect of government support on innovative activities of firms can not be expected because of the multiplicity of interpretations.

III.3. Independent variables specific to equation (2)

The determinants of R&D expenditure are essentially related to spillover effect, acquisition of external technology and firms' partnerships.

III.3.1. Spillover

The discussion on the linkage between internal and external R&D strategies has given prominence to the role of technological spillover. Acquiring knowledge and technology from the outside may not be neutral to a firm's R&D decisions. On the one hand, spillover may discourage and hence substitute for a firm's own research investment. If firms can benefit from other firms' R&D expenditure, there will be fewer incentives to invest in their own R&D. On the other hand, as reviewed supra, it is increasingly stressed in the literature that when inter-firm transfers occur, they are not necessarily an all-or-nothing substitute for in-house R&D (Veugelers, 1997). Firms can benefit efficiently from outside R&D if they improve their own absorptive capacity by investing in R&D. We think that the intensity of spillover that can benefit to a particular firm depends essentially on its own R&D. Therefore, we define spillover that can benefit to firm i in sector s :

$$Spillover_{is} = \sum_{j \neq i} RD_{js} (m_1 + m_2 RDDEP_i)$$

where RD_{js} denotes the R&D expenditures of firm $j \neq i$ belonging to the same sector s of the firm i ; $RDDEP_i$ is a dummy that takes on the value of 1 if the firm has its own R&D department with full-time R&D personnel. m_1 is the estimated parameter specific to the direct spillover effect and m_2 is the one associated to the spillover cross effect, i.e., absorptive capacity.

Given the lack of empirical studies on the issue, there is no established standard proxy to measure the absorptive capacity. According to theoretical literature, reviewed supra, the choice of $RDDEP_i$ seems to be a good proxy. Of course, we are aware that this measure

includes only spillover within an industry and does not take into account spillover between industries through technological proximity¹⁰.

III.3.2. Acquisition of external technology

Firms' expenditure on acquisition of external technology includes technological acquisition embodied in equipment as well as licensing and patent expenditures. The purchase of technological assets can be seen as complement or substitute to own R&D expenditures. We consider three qualitative variables according to the kind of acquisition: *Buy-NEM* takes on the value of 1 if the firm buys new equipments or materials; *Buy-RNT* takes on the value of 1 if the firm buys radically novel technology; *Buy-NTP* takes on the value of 1 if the firm buys new production techniques.

Furthermore, we have introduced a variable which reflects the changes in the firm's organization due to the acquisition of new technological assets. *Change-Org* takes on the value of 1 if the firm makes changes in internal organization related to the introduction of new technologies.

Also, the purchase of patents can be seen as an acquisition of external knowledge. Empirical studies use patents as a proxy for the underlying pattern of technological change (Cantwell and Fai, 1999) or as an indicator of competences' accumulation and growth of technological base of the firm (Cantwell and Piscitello, 2000). Therefore, we consider a qualitative variable, *Buy-patent*, that takes on the value of 1 if the firm purchases patent, else 0.

III.3.3. Partnerships

Empirical studies testing the link between co-operation and R&D activities find ambiguous results. Do partnerships simply substitute for in-house R&D (because of high costs and risks of R&D activities), or can it complement/enhance the latter (to better benefit from technological diffusion between partners)? For instance, Kleinknecht and Van Reijnen (1992) find a significant role for R&D intensity only for co-operation between private firms and public research institutes. However, König *et Al.* (1994) identify no significant relationship between R&D intensity and technological co-operation. On the other hand, Colombo and Garrone (1996) consider the Granger causality relationship between a firm's R&D intensity and its cooperative technology agreements. Finally, Fritsch and Lukas (2001) obtain a significant link between R&D intensity and cooperation only in respect to relationships with suppliers and research institutes. The growing importance of collaborative R&D strategies is captured here through the variable *Partnerships*, a dummy variable which takes on the value 1 if the firm is engaged in R&D relationships, else 0¹¹. A negative impact

¹⁰ Unfortunately, we have no measurement in our database, or in other databases in Tunisia, that allows an evaluation of this kind of spillover.

¹¹ No indication can be given on the importance of co-operation in terms of budgets spent on cooperation, as well as the form in which cooperation prevails. In the survey, cooperation includes all kinds of partners, especially public institutions, organisms, centers and laboratories.

means that firms who co-operate invest less in R&D, i.e., there is substitution while a positive effect implies that the more the firms have collaborative R&D strategies, the more they invest in their own R&D, i.e., there are complementarities.

III.3.4. Market share

There is a long tradition in industrial organizations of linking innovations to market structures, i.e., how firms and markets should be organized to improve industrial innovation (see Cohen and Levin, 1989, for a survey). Several arguments have been offered to justify a positive effect of firms' market share on inventive activity and R&D investment such as scales economies in the technology of R&D, higher returns from R&D, the spread of fixed costs across a larger volume of sales, etc.. On the other hand, counterarguments to this proposition have also been suggested such as the bureaucratization of inventive activity in large firms. Also, organization theory stresses the various inefficiencies associated with a large market power (Henderson, 1993). Even at a geographical level, Porter (1990) argues that local competition, as opposed to local monopoly, fosters the pursuit and the rapid adoption of innovation. In our work, the market share of the firm i is defined as its turnover divided by the total turnover of firms $j \neq i$ and that belongs to the same primary industry of firm i . This measurement is established at the three-digit level according to the INS nomenclature.

Finally, we introduce activities dummies to correct fixed industry effects by capturing various technology dimensions as stressed by several authors (e.g. Teece, 1986; Levin et al., 1987; Breschi et al., 2000) such as technological opportunities, appropriability regimes and dynamic aspects of demand. Four significant industry dummies are retained in our analysis: Mechanical and Metallurgical industries (MMI), Electric, Electronic and household equipment (EEHE), Leather and shoes industries (LSI), Textile and Clothing industries (TCI) and Chemicals industries (CHEM).

IV. The results

The model is estimated using the maximum likelihood method and in only one stage using "Full Information Maximum Likelihood, i.e., FIML. This method improves the efficiency of the estimates in relation to the two-stage estimation method. In particular, it corrects the non observable heterogeneity by the estimation of scale parameters (ρ and σ_1). The λ estimation corrects the selection bias in R&D investment equations.

IV.1. Estimating the probability to innovate

The estimation of the Heckman-Lee qualitative block generates selectivity corrective terms. Also this model enables us to identify determinants of innovation. In Table 2 column (2) presents results of innovation probability estimation using the "FIML" method, whereas, as a rough guide, column (1) proposes results of estimation by a simple probit model. Differences between the estimates and their significance in the two columns would be explained by the heteroscedasticity correction in column 2, which means by the correction of the non observable heterogeneity in the evaluation of the probability to innovate.

The estimation results highlight the innovation determinants. Firms which performed R&D activities during the period 2002-2005, record an increase of their probability to innovate, as compared to those not carrying out any R&D activities. This result is in line with most recent studies on innovation determinants (Romijn and Albaladejo, 2002; Galende and Fuente, 2003 and Vega-Jurado et al., 2008). As noted by Negassi (2004) even if not all innovative companies carry out research, they nevertheless profit from research performed by others through an appropriate organization. Accumulation of knowledge in making R&D activities enables firms to have a greater probability to innovate.

Table 2: Estimation of product innovation probability

<i>Variables</i>	<i>Dichotomic Probit</i>		<i>Heckman-Lee (H-L)</i>	
	<i>(1)</i>		<i>(2)</i>	
Constant	-0.21543	(0.28697)	-0.51118	(0.27016)
Size	0.01282	(0.00839)	0.01110	(0.00809)
Membership of group	-0.18176	(0.18019)	0.15663	(0.17792)
Public capital	-0.01976***	(0.00439)	-0.01489***	(0.00427)
Foreign capital	-0.00488**	(0.00215)	-0.00192	(0.00215)
Human capital	1.37805	(1.17483)	0.64551	(0.94794)
Skills	0.18853***	(0.06632)	0.16863***	(0.05758)
R&D activities	0.54321***	(0.17537)	0.62170***	(0.15804)
Experience in innovation	0.52665***	(0.18117)	0.34394**	(0.16756)
Public subsidies	0.36565**	(0.19337)	0.01450	(0.18752)
Sectors				
CHEM	0.11636	(0.30798)	0.25391	(0.29238)
TCI and LSI	-0.26231	(0.23802)	-0.25296	(0.21432)
MMI and EEHE	-0.10534	(0.21825)	-0.06487	(0.20302)
Sigma 1		-	5.010545***	(0.30769)
Number of observations ¹²		300		300
Wald (chi2)		73.36***		591.71***
Pseudo R-squared		0.1991		-

The numbers between () are the estimated standard deviation.

(***) Significant at 1% ; (**) Significant at 5% ; (*) Significant at 10%.

The second important result is the positive and significant impact of past experience on innovation activities. This means that firms with previous experience in innovation programs

¹² After removing the enterprises that responded partially to the questionnaire, we ended up with the sample of 300 enterprises.

even unfinished ones are more likely to be innovating. The main idea here is that knowledge that has been used to start past innovation projects can also be used to produce current innovations. Implicitly, we suppose that the depreciation rate of innovative abilities and competences may be very small. This result is in conformity with recent studies investigating the extent to which being successful in past innovative activities affects the probability of being successful in current innovative activities (Duguet and Monjon, 2002 and Raymond et al., 2005).

The estimates for government sponsored R&D are significantly positive only for the probit specification, suggesting that subsidies seem to stimulate innovation production. These results are consistent with those of Negassi (2004), Sadraoui and Ben Zina (2007) and González and Pazó (2008). Because of the high costs in relation to innovation and R&D activities, public subsidies even when insufficient can be seen as an incentive to perform R&D activities and to produce innovations. More precisely small firms in Tunisia have some difficulties, in financial terms, keeping up with rapid rate of technological change and apply more frequently for the several forms of government funding.

When investigating the extent to which the ownership structure of the firms can affect their likelihood to innovate, we find two main results. Firstly, the firms whose capital is partly or even totally held by the State have a weak innovation probability with reference to private ones. The variable *public capital* negatively affects probability to innovate. Capital structure based on the presence of public funding can inhibit the carrying out of innovation projects. It is well known that the bureaucracy and lack of communication which characterize public firms can also reduce incentives to innovate for firms even partially owned by the State. Secondly, foreign controlled firms are less likely to innovate (only in probit specification). Foreign investors when controlling totally or partially domestic firms are not motivated by their capacity to innovate but rather by the low costs of labor. Therefore, foreign controlled companies are more often subcontracting for multinational companies and rarely benefit from foreign knowledge to improve their capacity to produce innovation. As suggested by Veugelers (1997), this might reflect the centralization of R&D within the foreign parent company resulting in lower own R&D activities within local subsidiaries.

Firms that require many qualified staff are those whose innovation probability is the greatest. However, our estimates show that human capital does not seem to have any impact on probability to innovate. These results suggest that innovating firms have lower rates of skilled employees in R&D but have greater needs for qualifications as compared to non-innovating ones. We can explain this finding by the fact that Tunisian firms have generally little structure of research with full-time R&D personal which make the human capital ratio very low, whereas firms are doing research without any department of R&D. This result is consistent with the findings of Negassi (2004) which confirm that the hiring of skilled personal is positively related to the capacity to carry out innovation projects. In addition, human capital also appears to be a way of capturing externalities. Accordingly, companies which have small R&D budget benefit from externalities by hiring skilled employees.

Companies' skills enable them to improve their absorptive capacity and also to enhance their capacity to innovate.

The variables *size* and *group membership* have no significant effect on the probability to innovate. The industries dummies are gathered into three dummy variables which are included to capture inter-industry differences in technological opportunities, but could also be measuring other unspecified industry effects, such as demand pull factors. However, these dummy variables are not significant. This result can be related to the specific character of the sample where companies are very dispersed over manufacturing activities considered.

Finally, and with regard to the model adequacy quality, Wald statistic is significant at 1%, indicating the global pertinence of variables introduced in the model. Sigma 1 estimation is significant, indicating both the existence and the correction of heteroscedasticity problem.

IV.2. Estimating R&D equations

Estimation of the innovation probability in the previous section enables – besides identifying of innovation determinants – computing correctors' terms of selectivity to be introduced in the estimation of the R&D expenditures equations'. Explaining factors of R&D investment are assumed to be different according to whether the firm is innovating or not.

We have estimated two semi-logarithmic R&D investment equations according to innovation regimes (innovating and non-innovating firms) corrected from selectivity bias. In table 3, columns (2) and (3) present H-L estimations results related to these two equations. Column (1) of this table proposes GLS estimation of the same specification for all firms. Finally, we should point out that table 4 of appendix 1 presents, as a rough guide, GLS estimation results of the two equations of investment according to innovation regimes. The results of quantitative block estimation show that most R&D investment determinants do not have the same impact for innovating and non-innovating firms.

Thus, for innovating firms, the higher the turnover is, the more the firm invests in R&D. It follows that R&D expenditure increases with turnover. This is in line with most other studies which tend to find significantly positive effects of size on R&D intensity (Veugelers, 1997). The same role is played by the total employment in R&D. Therefore, the more a firm appoints staff to R&D operations, the more its level of investment is raised. However, these two effects are not verified for non-innovating firms since their estimated coefficients are not significant. Firms which belong to a group have a greater level of R&D investment. This impact is observed for innovating firms but also for non innovating companies.

Foreign participation in a firm's capital structure has a negative and a non significant impact on R&D expenditures for innovating firms whereas its effect is significantly positive for non-innovating firms. This result means that foreign investors are more likely to increase R&D investment of their non-innovating subsidiaries in technological based industries in order to pursue a catching up process. However, if Tunisian subsidiaries of multinational companies are subcontracting in industries like textile and clothing, they have greater incentives to reduce production costs and little motivation to invest in R&D activities. In this

last case, firms are more interested in training programs for employees. The same effect is observed for the variable *public capital* which means that R&D investments increase with the share of government capital participation only for non-innovating firms. Partnerships play an important role in explaining R&D investment. This effect is positive and significant only for innovating firms. This result suggests complementarities between co-operation and R&D activities, i.e., innovating firms increase their R&D expenditures to better benefit from technological diffusion of knowledge from their partners.

Table 3: Estimation of R&D investment function: Heckman-Lee selection model

<i>Variables</i>	<i>All firms</i>		<i>Innovating firms</i>		<i>Non-innovating firms</i>	
	<i>(1)</i>		<i>(2)</i>		<i>(3)</i>	
	<i>GLS</i>		<i>H-L</i>		<i>H-L</i>	
Size (Turnover e-07)	0.00353	(0.02153)	0.06539*	(0.03925)	0.00040	(0.05093)
Membership of Group	4.30073***	(0.46083)	2.970***	(0.63617)	3.15047***	(0.9347)
Human capital	0.03279*	(0.02033)	0.04624**	(0.02399)	0.03088	(0.04856)
Foreign capital	0.01614**	(0.00571)	-0.00529	(0.00932)	0.01575*	(0.00967)
Public capital	0.05061***	(0.01304)	-0.0285	(0.02477)	0.08776***	(0.02057)
Partnerships	2.66744***	(0.49950)	2.15251***	(0.62037)	0.80095	(0.90922)
Buy-NEM	2.98498***	(0.52568)	3.22878***	(0.60025)	-0.41596	(2.3618)
Buy-RNT	1.52568**	(0.68941)	1.47021**	(0.67291)	-	
Buy-NTP	3.7309***	(0.51936)	2.8512***	(0.60926)	3.38832***	(0.86135)
Change-ORG	1.27038**	(0.56628)	0.93385	(0.67437)	1.36865	(1.00281)
Buy-patent	0.03522	(1.11132)	0.90986	(1.33059)	-3.2656	(3.60793)
Spillover*e-07 ¹³	0.23063***	(0.04446)	0.18727***	(0.05203)	0.04593	(0.07696)
Spillover-depar.*e-07 ¹⁴	-0.22268***	(0.08151)	-0.18049**	(0.08458)	-0.09437	(0.2268)
Market share	6.73564***	(2.22839)	6.34653***	(2.5129)	-2.2726	(5.30476)
Rho			0.83725***		(0.06228)	
Lambda			4.19508***		(0.50844)	
					4.31495***	
					(0.57840)	
Number of observations	300		206		94	
F-statistic	127.14***		-		-	
LR Test(rho=0)					38.39***	

¹³ The direct effect of external R&D $\left(m_1 \sum_{j \neq i} RD_{js} \right)$

¹⁴ The cross effect between external R&D and a firm's own R&D department $\left(m_2 \sum_{j \neq i} RD_{js} (RDDEP_i) \right)$

R-squared	0.8333	-	-
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The numbers between () are the estimated standard deviation.

(***) Significant at 1 %, (**) Significant at 5 %, (*) Significant at 10 %.

Included as external channels of acquiring external knowledge, the buying of technologies either embodied or disembodied, tends to enhance R&D investment. The use of new equipments and materials (*Buy-NEM*), of extremely new technology (*Buy-RNT*)¹⁵ and of new technologies of production (*Buy-NTP*) would increase, *ceteris paribus*, the innovating firms' investment in R&D. However, the variable related to organizational change (*change-ORG*) has no significant effect. All these results can be related to the fact that most of these expenditures require own adaptation in terms of R&D investment to yield innovative output.

Coefficient associated to variable *Spillover* is positive and significant only for innovating firms, i.e., there is a spillover effect for innovating firms. However innovating firms which have R&D department can better benefit from external R&D in the industry. The coefficient associated to the interaction variable *Spillover-department* exerts a significant effect. It should be pointed out that according to these results there are spillover effects for innovating firms having an absorptive capacity. Innovating firms can not benefit from R&D investment performed by other firms of the same industry if they do not have R&D department. We should point out that this impact is negative indicating a substitute relationship. The more the firm benefits from R&D performed by others firms through its R&D cell, the less the firm invests in its own R&D. These results are in contrast with Cohen and Levinthal (1989) assumption which means that firms invest in their own R&D to better benefit from technological spillover (complementary character). They are also in contrast with Gustavsson and Poldahl (2003) findings on Swedish firms. However, our results highlight the role of absorptive capacity because in spite of the negative effect, our findings show that firms are able to reduce their expenditures in R&D only if they already have their own in-house staffed R&D department, i.e., they have developed an absorptive capacity. Similar findings are found in studies testing the relationship between internal R&D expenditures and cooperative R&D agreements (Becker and Dietz, 2004 and Negassi 2004).

When considering all firms (column 1) we note that, for the most part, variables have the same role in explaining R&D expenditure as in H-L quantitative estimation. Only one variable (organizational change) has positive and significant impact in the full population specification whereas there is no significant effect for this variable in the H-L model. This result suggests that the organizational change has no specific effect related to innovation regime.

Finally, the coefficient of the interrelationship (ρ) between random terms of the two equations is significant. This result confirms the relevance of the specification (considering the relationship between innovation situation and R&D investment) that we have kept and

¹⁵ This variable has been withdrawn from equation (3) in table 3, relative to the non-innovating enterprises, because of co-linearity problem.

estimated. In addition, Mill's ratios (λ) are significant for the two equations. This result shows the existence of selectivity bias that we have corrected.

IV.3. Post estimation tests

In order to support our model's specification, we have achieved a set of statistical tests aiming at strengthening the results that we have obtained. Tables 5 and 6 of appendix 3 propose two tests of average equality of R&D investments for the two classes of firms (innovating or not). Thus, we compare the "FIML" estimated averages (table 5), and the observed averages (table 6). Firstly, the results show that averages for the two classes are different and that innovating firms present a higher level of R&D investment average. Secondly, we can see that the differences between observed and estimated averages for the two groups are very weak. This result confirms the efficiency of our estimation.

Our model has two kinds of assumption. The H-L specification assumes *i*) explicitly the existence of differences as regard to determinants of R&D investment between the two situations (innovating and non-innovating firms); and *ii*) implicitly the existence of differences in R&D investment between innovating and non-innovating firms. On the one hand, estimation results of the H-L model show the existence of meaningful differences between determinants of R&D expenditure for the two classes of firms (explicit hypothesis). On the other hand, averages' equality test for R&D investment between two classes of innovation regimes point out significant difference in favor of innovating firms as regard to R&D expenditures (implicit hypothesis). When considering these two results simultaneously, we can put forward that there is a real behavioral difference between innovating and non-innovating firms.

V. Conclusion

Although the availability of external technology may discourage own research investment by the receiver firms, the literature provides arguments to underline the complementarities between in-house R&D and external knowledge, at least when in-house R&D is tuned to absorb external knowledge. The dual role of R&D provides arguments to understand why both innovating and non-innovating firms invest in R&D. This paper examines the relationship between R&D expenditures and firms' innovation. More precisely, we estimated the determinants of a firm's innovation and subsequently we estimated the determinants of R&D investment considering the selectivity problem related to the innovation situation (innovating/non-innovating). Therefore, we have used a Heckman-Lee specification to estimate the model. The analysis extends the classical set of explanatory variables for internal R&D, such as size, ownership structure, membership of group and human capital and include the impact of spillover, channels related to acquisition of external technology and partnership.

The results on determinants of innovation confirm the positive impact of R&D activities, human capital quality, past experience in innovation and public subsidies whereas

ownership structure (state and foreign owners) have a negative impact on the probability of firm to innovate. At the second stage, when estimating the determinants of R&D expenditures for the two groups of firms (innovating and non-innovating) we find interesting results. There are spillover effects only for innovating firms which have an absorptive capacity. Innovating firms can not benefit from R&D investment performed by other firms in the same industry if they do not have R&D department. This effect is negative showing that the more a firm benefits from R&D performed by other firms through its own in-house staffed R&D department, the less the firm invests in its own R&D. Also channels for acquisition of external technologies play an important role in explaining R&D expenditures. Finally, ownership structure has a significant impact on R&D investment especially for foreign controlled firms. The effect is significant and positive for non-innovating firms.

These results provide new empirical evidence on determinants of innovation and R&D investment in developing countries such as Tunisia (such studies remains scarce in developing countries). They clearly show the complexity of the relationship between the determinants of innovation and those of R&D investment. More work is needed to identify specific firm characteristics generating the absorptive capacity such as technological environment in which the firm is embedded, its cumulative experience and central positions in networking, as well as the identification of inter-industry spillover effects.

These findings have implications for our understanding of innovation policy. Because of the beneficial effects of R&D effort both for innovating and non-innovating firms through spillovers, public grants and subsidies should be rather a complement than a substitute to private R&D investment. The amount and kind of public subsidies should be chosen according to the in-house R&D effort. Some incentive mechanisms can be introduced to put less innovating firms in a catching up process. Public authorities should encourage firms to recruit high qualified employees to enhance their absorptive capacity. Also, economists have long cautioned policymakers about the welfare costs of policies, such as patents, that curtail the negative incentive effects of spillovers by conferring monopoly power. Analysis of the role that R&D plays in firm learning adds another dimension to the evaluation of the welfare effects of patents and similar policies. In particular, it implies that the negative incentive effects of spillovers and, thus, the benefits of policies designed to mitigate these effects, may not be as great as supposed.

Appendix 1

Table 4 – R&D investment estimation according to the innovation regimes

<i>Variables</i>	<i>Innovating firms</i>		<i>Non-innovating firms</i>	
	<i>GLS</i>		<i>GLS</i>	
Size (Turnover*e-07)	0.03947	(0.02689)	-0.01569	(0.03057)
Membership of group	3.62756***	(0.56576)	5.26423***	(0.91358)
Human capital	0.03455*	(0.02066)	0.04257	(0.0416)
Partnership	2.47324***	(0.62017)	3.08392***	(1.01288)
Foreign capital	0.01152	(0.00878)	0.01174	(0.012722)
Public capital	0.00147	(0.01989)	0.06919***	(0.02017)
Buy-NEM	3.78154***	(0.57553)	2.24158	(3.61045)
Buy-RNT	1.89797***	(0.68806)	-	
Buy-NTP	3.30109***	(0.65056)	4.88211***	(0.90194)
Change-ORG	0.81513	(0.71135)	1.48903	(1.25597)
Buy-patent	0.99625	(1.04962)	-4.61326***	(1.30323)
Spillover*e-07	0.22995***	(0.05039)	0.2362**	(0.09479)
Spillover-depar*e-07	-0.25891***	(0.09109)	-0.13147	(0.18657)
Market share	7.90097***	(2.28272)	2.07885	(3.88448)
Number of observations	206		94	
F-statistic	109.46***		30.32**	
R-squared	0.8494		0.8296	

The numbers between () are the estimated standard deviation.

(***) Significant at 1 %, (**) Significant at 5 %, (*) Significant at 10 %.

Appendix 2

Table 5 – Equality tests of estimated average of R&D investments

Variable	Observations	Mean	Std. err.	95% conf. interval
Ln(RD)1 First régime: innovation	206	11.0297	0.084	10.865 -- 11.1953
Ln(RD)0 Second régime: non-innovation	94	10.1398	0.1765	9.7894 -- 10.4902
Combined	300	10.7508	0.0832	10.5871 -- 10.9146
Difference = ln(RD)1 – ln(RD)0		0.8898	0.1954	0.5035 --1.2763

H0: difference = 0

T = 4.5538

Pr(difference = 0) = 0

Table 6 – Equality tests of observed average of R&D investments

Variable	Observations	Mean	Std. err.	95% conf. interval
Ln(RD)1 First régime: innovation	220	10.9467	0.1993	10.5539 -- 11.3395
Ln(RD)0 Second régime: non-innovation	101	9.9585	0.3609	9.2425 -- 10.6744
Combined	321	10.6358	0.1792	10.2833 -- 10.9882
Difference=ln(RD)1 – ln(RD)0		0.9883	0.4123	0.1742 --1.8023

H0: difference = 0

T = 2.3971

Pr(difference = 0) = 0.0177

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