ECONOMIC RESEARCH FORUM
منتدى البحوث الاقتصادية

2009

working paper series

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Working Paper No. 484

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April 2009

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Abstract

The purpose of the paper is to produce new empirical evidence regarding the determinants of R&D investment by Tunisian firms, through introducing the relationship between R&D expenditures and innovation effort of firms. We suppose that factors explaining in-house R&D are not the same according to whether the firm is innovating or not. Our empirical analysis utilizes econometric models of selectivity correction (Heckman, 1976-1979; Lee, 1976-1978) and considers a sample of 320 firms during the period 2002-2005. On the one hand, econometrics results show a positive impact of R&D activities, human capital quality, past experience in innovation and publics subsidies on probability to innovate of firms whereas ownership structure (state and foreign owners) have a negative impact. While on the other hand, 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 and which have an absorptive capacity. 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 positive for innovating firms and negative for non-innovating firms.

1. Introduction

Innovation and R&D activities are important competitiveness factors for both firms and nations. Despite constant academic efforts and a growing literature on the relationship between R&D activities 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. Although Tunisian firms are considered as slightly innovative, have difficulties to innovate, their R&D intensity is by far more important. Because of the gradual trade liberalization pursued by Tunisia (accession to the GATT agreements and free trade association with the European Union in 1995), Tunisian companies have 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, more precisely for Tunisia, the innovation activity is more of an adoption of foreign technologies; this requires efforts in order to match the domestic context. By product innovation we mean products new to the firm rather than products new to the relevant market. The first category of innovation, very likely in developing countries like Tunisia appears as imitative strategies (taking the world market as a reference point) while the latter implies a radical innovation strategy (generally observed in developing countries).

The relationship between R&D activities and firm's performance is far from being a recent field of research, as shown in surveys by Mohnen (1996), Griliches (1995) or Mairesse and Sassenou (1991) among others. It is now well known that, besides the impact of the firm's own R&D expenses, positive externalities stem from other firms' R&D activities, i.e. there are diffusion or spillover effects. Yet 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 utilize technological knowledge which is already 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 scope of this paper is to report new empirical evidence related to Tunisian firms about the implications of this dual role of R&D for firm's incentive to invest in R&D according to whether the firm is innovating or not.

Survey data about R&D activities and innovation of Tunisian firms (carried out by the Ministry of Scientific Research and Competences Development in Tunisia in 2005) is used to investigate determinants of R&D expenditures and innovation. More precisely, the purpose of this paper is to produce new empirical evidence about the determinants of R&D investment, while introducing the relationship between R&D expenditures and the 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 activities). Thus we can expect that R&D investment will be explained by the absorptive capacity. Our ambition in this paper is twofold.

First, the determinants of innovation for Tunisian firms are highlighted. Further, the most frequently 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 become of great interest for Tunisian manufacturing firms only since the past two decades.

Indeed, in order to help Tunisian companies to face foreign competition[1], 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, consisted of technical assistance, training, subsidies, and infrastructure upgrades aimed at encouraging and assisting Tunisian private sector restructuring and modernization. In this paper, we examine the effect of public subsidies related to this program on innovation activity of firms.

Second, R&D expenditures of Tunisians firms have grown significantly these 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 to carry out new product or process whereas non-innovating enterprises invest in R&D to enhance their absorptive capacity. Thus, besides the usual determinants of internal R&D expenditures (such as size, market share, collaboration, etc.) we consider the effect of technological spillovers.

In the literature on the relationship between R&D and innovation, there is a large debate about the complementarities and the substitutability between internal and external R&D. Although the availability of external technology may discourage —and hence substitute for — internal 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 of foreign equipments or goods (Grossman and Helpman, 1995), buying patents (Jaffe, 1986), using new materials and building 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. One of the reasons listed is that drawing on both internal and external R&D requires resources. Since organizations are resource-constrained, firms often display a tradeoff between external and internal R&D. This explanation draws on the distinction between exploitation and exploration activities discussed by Levinthal and March (1993) which has been further investigated by Greve (2007) through looking into the slack resources of firms revealing that slack is a prerequisite for pursuing a combined exploration and exploitation strategy. In a similar fashion, Laursen and Salter (2006) discussed the extent of drawing on external sources arguing that the case of being “too open” is valid highlighting that firms have an attention limitation. Accordingly, searching among too many external sources will lead to an information overload or a search that is too superficial, and thus decreasing their innovative chances

These complementarities between R&D expenditures and the innovating/non-innovating situations of Tunisians firms provide some insights about innovation policy for public authorities. In order to help the 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, networks of actors 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 to develop their own system of

[1] The globalization process began in Tunisia in the 1970s, but real measures of liberalization of trade and capital inflows were adopted in the middle of 1990s, in particular with the membership of Tunisia in the WTO and signing, in 1995, the Tunisia – European Union free trade agreement.

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 model to be estimated which takes into account the relationship between innovation and R&D investment. Section 3 describes our sample of firms and the measures of variables. Section 4 presents and analyzes our econometric results. Finally, Section 5 concludes the paper and provides some recommendations and policy implications.

2. Econometric Specification of the Model

The model we estimate should take into account the link between the R&D investments and innovation activity of firms. The determinants of R&D expenditures for one firm are not independent from its innovating or non-innovating strategies. 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 a firm.

Our empirical analysis utilizes econometric models of selectivity correction. More precisely, the analysis presents a direct adaptation of the Heckman (1976-1979) model combined with the development of Lee (1976-1978). The model with two regimes corrects 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.

Firstly, we consider the determinants of the product innovation decision[2]. 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 for 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 in product and 0 otherwise. We thus estimate the probit model to explain the probability of a firm to innovate in a product. These estimations will be realized for all firms of the sample distinguishing between two innovation situations:

$j = 1$ if firm innovates

$j = 0$ if firm does not innovate

In order to verify if the R&D investments function depends on the innovation situation of firms, it is important to consider selection mechanism related 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 expenditures. The first stage results will be utilized in estimating the R&D investment function (two equations will be considered according to the innovation situation of the firm). This method is interesting because it enables us to isolate specific effects of independents variables, and more precisely of the real effect of innovation regime on R&D investment.

[2] We focus our analysis only on product innovations because the relationship between R&D investment and innovation activities is more significant for product innovations than for process ones.

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

$$\begin{cases} Y_{ij}^{*} = X'_{ij}\beta + \mu_{ij} & (1) \\ Z_{ij} = W'_{ij}\alpha + \gamma'\,\hat{\lambda}_j + \varepsilon_{ij} & (2) \end{cases}$$

Where variables and parameters are defined as follows:

Y_{ij}^{*} denotes that firm *i* have situation *j* of innovation (*i* = 1, . , N and *j* = 0,1).

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

Z_{ij} is the log of R&D expenditures of firm *i* in situation *j*.

α, β *and* γ are the estimated parameters.

$\hat{\lambda}_j$ are ratios of Mills. $\hat{\lambda}_j = \dfrac{\phi(X'_{ij}\beta)}{\Phi(X'_{ij}\beta)}$ are correctors terms of selectivity.

$\phi(.)$ and $\Phi(.)$ 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 (qualitative structure of the model). Equation (2) represents two equations related to R&D investment (quantitative structure of the model). This econometric model supposes the estimation of qualitative structure at the first stage in order to calculate corrector's terms of selectivity $\hat{\lambda}_j$ (called Mills ratios in simple process of selection) which measures the fraction between the density function of normal rule and the distribution function of the same rule, as a function of individual characteristics.

3. 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 Development in Tunisia[3]. The survey was conducted during the period 2002-2005 on a sample size of 300 firms[4] (all manufacturing activities are considered).

Manufacturing firms, with at least 10 employees, answered questions primarily concerned with R&D activities and expenditures, 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. Let us note that 42.3% of firms have done R&D activities, 27,6% of them continuously and 14,7% occasionally. The highest levels of R&D expenditures were in electric and electronic industries and in chemical industries. The distribution of firms according to their activities is given by the following Table 1. Column 2 of this table gives the percentage of innovating firms in each sector.

For innovation projects during the period of study, 70% of firms are innovating. We can note that 51% have at least one product innovation, 49% have at least one process innovation, and 34% have at least abandoned or unfinished innovation. In terms of number of firms, the most

[3] *Ministère de la Recherche Scientifique et du Développement des Compétences en Tunisie.*

[4] We note that the sample size was initially of 586 firms. But non- responses concerning, especially, the dependent variable, i.e. R&D investment, reduced the sample size to 300 firms correctly observed.

innovative industries are Farm – Produce industry (19%), Electric, Electronic and Electro mechanic industries (13%) and finally Mechanics, Metallic and Metallurgic industries (12%).

We consider R&D investment and innovation to be a function of industry and the characteristics of the firm. We have three sets of independents variables.

3.1 Independents Variables Common to Equations (1) and (2)

3.1.1 Size

Firm size is measured by the log of its 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 appears 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, the flexibility, adaptability and efficient internal communication allow smaller companies to be quicker in responding to external opportunities and changes. Empirical results are very divergent about 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 large firms in aggregate, they produce almost twice as many innovations on a "per employee" basis[5]. Smaller size may have positive effects on R&D activities such as better networks of communication and co-ordination, informal controls, etc.

3.1.2 Membership of Group

Group is a dummy variable which takes the value 1 if firm belongs to a group and 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 so has a higher probability to be innovating (Paul et al., 2000). Also, firms belonging to a group have better information about opportunities in the market. However, firms of a group should invest in their own R&D to enhance their absorptive capacity.

3.1.3 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. Likewise, if the firm is state-controlled, the innovation and R&D strategies may be influenced negatively or positively. The presence of public authorities in the capital of a firm can be either a source of complexity and loss of flexibility or a source of great power in the market. To investigate the effect of capital structure of the firm on its R&D expenditures and innovation activities, we consider two measures. The first one denotes the share of foreign capital (*Foreign Capital*) and the second is the percentage of government capital participation (*Public Capital*).

3.1.4 Human Capital

Among the resources necessary for the generation of innovations within a firm is the availability of a team of scientists and technicians with suitable qualifications and know-how in R&D activities. This human capital implies higher skills and knowledge in 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

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

qualified labor (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 a five point's scale of *likert*) that firm gives to the qualification of personnel.

3.2 Independents Variables in Equation (1)

The determinants of innovation include variables related to the firm's characteristics.

3.2.1 R&D Activities

It is well known now that R&D investment can merely be seen as an important input to innovative activities. We cannot use R&D expenditures as a measure of R&D activities in a firm 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 and 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.

3.2.2 Experience in Innovation

Firms which have unfinished projects of innovation would be potentially innovating ones. They can be viewed as knowledge-based organizations. Firms which lunch 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 use a dummy variable (*Experience-innovation*) that takes on the value of 1 if the firm has unfinished projects of innovation and 0 otherwise.

3.2.3 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 be precise if they have acquired in the past five years any forms of public subsidies[6]. So we construct a synthesized variable (*public subsidies*) which takes the value of 1 if the firm responses positively for at least one form of subsidies and 0 otherwise.

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 of 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 the firms an absorptive capacity which can be 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 for the projects they favor. 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 cannot be expected because of the multiplicity of the interpretations.

[6] 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), The National Program of Research and Innovation (PNRI), Incentive regime to innovation in the field of information technology (RITI), and the Program of researcher's mobility (Mobilité)

3.3 Independent Variables in Equation (2)

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

3.3.1 Spillover

The discussion on the linkage between internal and external R&D strategies has made eminent 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 own research investment. If firms can benefit from other firm's R&D expenditures, 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 one firm depends especially on own R&D. Therefore, we define spillover that can benefit firm *i* in sector *s*:

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

Where RD_{js} denotes the R&D expenditures of firm $j \neq i$ belonging to the same sector s of the firm i; RDDEPi is a dummy that takes on the value of 1 if the firms has its own R&D department with full-time R&D personnel. Given the lack of empirical studies on the issue, there is no established standard proxy to measure absorptive capacity. Following the theoretical literature, reviewed supra, the choice of RDDEPi seems a good first proxy. Of course, we are aware that this measure includes only spillovers within an industry and does not take into account spillovers between industries through technological proximity7.

3.3.2 Acquisition of External Technology

Firms' expenditures on the acquisition of external technology include technological acquisition embodied in equipment as well as licensing and patent expenditures. The purchase of technological assets can be seen as a complement or a 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 techniques of production.

Further, we introduce a variable which reflects the changes in the organization of the firms due to the acquisition of new technological assets. *Change-Org* takes on the value of 1 if the firm makes change in the internal organization associated to the introduction of new technologies.

Also, the purchase of patent 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 competence's accumulation and growth of technological base of the firm (Cantwell and Piscitello, 2000). We consider then a qualitative variable, *Buy-patent*, that takes on the value of 1 if the firm purchases patent, else 0.

3.3.3 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

[7] Unfortunately, we have no measurement in our database, or in others databases in Tunisia, that allows an evaluation of this kind of spillover.

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 for 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 and 0 otherwise[8]. A negative impact 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 is complementarities).

3.3.4 Market Share

There is a long tradition in industrial organization 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 firm market share on inventive activity and R&D investment such as scale 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 like the bureaucratization of inventive activity in large firms. Also, the 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 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).

4. The Results

Let's first note that the model is estimated by maximum likelihood method and in only one stage using "Full Information Maximum Likelihood (FIML)". This method improves the efficiency of the estimates in relation to the two stages estimation method. Particularly, it corrects the non observable heterogeneity by the estimation of scale parameters (rho and sigma 1). Finally the lambdas estimation corrects the selection bias in R&D investment equations.

[8] 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.

4.1 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 decision. 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 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 2002-2004, 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, 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.

The second important result is about the positive and significant impact of past experience in innovation activities. Firms having past experience in innovation programs, even if never finished, are more likely to be innovative. Such that, knowledge that has been used to start past innovation projects could also be used to produce current innovations. While Implicitly, supposing that the depreciation rate of innovative abilities and competences may be very small, this result is in conformity with 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; Raymond et al., 2005).

The second important result is about the positive and significant impact of past experience in innovation activities. So, firms having past experience in innovation programs, 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; Raymond et al., 2005).

The estimates for government sponsored R&D are significantly positive only for 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 associated with innovation and R&D activities, public subsidies even insufficient ones can be seen as an incentive to perform R&D activities and to produce innovations. More precisely, small firms in Tunisia have some financial difficulties to follow the rapid rate in technological change, and apply more frequently for the several forms of government funding.

When investigating the extent to which the ownership structure of the firm can affect its probability to innovate, we find two main results. First, the firms whose capital is partly or even totally held by State would have a weak innovation probability with reference to private ones. The variable *public capital* affects negatively the 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 bureaucracy and lack of communication which characterize public firms can also reduce incentives to innovate for firms even partially owned by the State. Second, foreign controlled firms have less probability 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 weak costs of labor. So 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 having an important need for qualified staff are those whose innovation probability is the most important. However our estimates show that human capital doesn't seem to have an impact on probability to innovate. These results suggest that innovating firms have lower rate 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 personnel making the human capital ratio very weak, as opposed to firms without an independent R&D department. This result is consistent with the findings of Negassi (2004) which confirm that the hiring of skilled personnel is positively related to the capacity to carry out innovation projects. In addition, human capital also appears to be a means of capturing externalities. Accordingly, companies which have a little budget of R&D benefit from externalities by hiring skilled employees. Companies' skills enabling them to improve their absorptive capacity also enhance their capacity to innovate.

The variables *size* and *membership of group* have no significant effect on the probability to innovate. The industries dummies are gathered into three dummies 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 regards 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 the heteroscedasticity problem. The H-L model specification seems to be suitable in explaining the determinants of innovation and R&D expenditures.

4.2 Estimating the R&D Equations

The Heckman-Lee model’s quantitative part supposes that the existence of an innovation situation (innovating/non-innovating firms) has an impact on R&D investment. In other words, the quantitative model of R&D investments assessment would depend on the behavioral model of the probability to innovate. Consequently, the determinants of R&D expenditures as well as their impact depend on innovation situation.

For that, 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 estimations results related to these two equations. The column (1) of this table proposes GLS estimation of the same specification for all firms. Finally, let's signal that Table 4 of appendix 1 presents, as a rough guide, GLS estimations results of the two equations of investment according to innovation regimes. The results of quantitative block estimation show that most R&D investment determinants don’t have the same impact for innovating and non-innovating firms.

Thus, the higher the turnover is for innovating firms, the more the firm invests in R&D. It ensues that R&D expenditures increase 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. So, 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 the non-innovating firms since their estimated coefficients are not significant. Firms belonging to a group have a greater level of R&D investment; this impact is observed for innovating firms as well as for non innovating ones.

Foreign participation in firm's capital structure has a negative and insignificant 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 subsidies 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 costs of production and so little motivations 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 public capital variable; R&D investments increase as the share of government capital participation for non-innovating firms only. 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, such that innovating firms increase their R&D expenditures to better benefit from technological diffusion of knowledge from their partners.

Included as external channels of acquiring external knowledge, the buying of technologies either embodied or disembodied, tends to enhance R&D investments. The use of new equipment and materials (*Buy-NEM*), extremely new technology (*Buy-RNT*)[9] and of new technologies of production (*Buy-NTP*) would increase, citrus paribus, innovating firm's investment in R&D. However, the variable related to organizational change (*change-ORG*) has no significant effect for non- innovating and non-innovating firms. 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.

In the same sense, the spillover in interaction with cell variable presents a negative and significant coefficient only for the first group, whereas it is not significant for the non-innovating enterprises. It should be pointed out that according to these results there are spillover effects only for innovating firms and which have an absorptive capacity. Innovating firms cannot benefit from R&D investment performed by other firms of the same industry if they do not have a R&D department. The coefficient associated to this variable (*Spillover*) is positive and significant, i.e. there is a spillover effect. However firms which have a 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 is only when explicitly taking into account absorptive capacity that external R&D becomes significant in explaining internal R&D. We should stress 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 spillovers (complementary character). They are also in contrast with Gustavsson and Poldahl (2003) findings about Swedish firms. But 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; Negassi 2004).

[9] This variable has been withdrawn from equation (3), Table 3, relative to the non-innovating enterprises, because of co-linearity problem.

In addition, other variables present non-significant coefficients for the two groups, which suggest the absence of their impact on R&D investment and that independently from the regime of innovation. It is the case of variables such as membership of group, partnership with its different shapes, the use of new materials or equipments, patent purchase and market share.

When considering all firms (column 1) we note that the most part of variables have the same role in explaining R&D expenditures as in H-L quantitative estimation. However,only one variable (organizational change) has a 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 there is no specific effect of an innovation regime organizational change.

Finally, the coefficient of the interrelationship (rho) between random terms of the two equations is significant. This result confirms the relevance of the specification that we have kept and estimated, i.e. which considers the relationship between innovation decision and R&D investment. In addition, Mill's ratio (lambda) is significant for the first equation. This result shows the existence of the selectivity bias that we have corrected.

4.3 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. First, the results of Breush-Pagan test[10] (applied on the two functions of R&D investment estimated by OLS) show the presence of heteroscedasticity. This assessment explains the reason for which we make estimations for the total population by GLS, and especially the estimations by FIML for the selection model.

In addition, 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). The results first show that averages for the two classes are different and that innovating firms present a higher level of R&D investment average. And second, 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 assumptions. The H-L specification assumes *i*) explicitly the existence of differences with regards to determinants of R&D investment between the two regimes of innovation; 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 expenditures 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 a significant difference in favor of innovating firms with regards 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.

5. Conclusion

Although the availability of external technology may discourage own research investments by the receiver firms, the literature provides arguments to stress 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 innovation of firms. More precisely, we estimate the determinants of firm's innovation and then we estimate the determinants of R&D

[10] See Appendix 2.

investment taking into account the selectivity problem related to the innovation strategy (innovating/non-innovating). So, we have used a Heckman-Lee specification to estimate the model. The analysis extends the classical explanatory variables for internal R&D, like size, ownership structure, membership of group and human capital to include the impact of spillover, channels related to acquisition of external technology and partnership.

The results about determinants of innovation confirm a positive impact of R&D activities, human capital quality, past experience in innovation and publics subsidies whereas ownership structure (state and foreign owners) have a negative impact on the firms' probability 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't benefit from R&D investment performed by others firms of the same industry if they do not have a R&D department. This effect is negative showing that the more the firm benefits from R&D performed by others 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 innovating firms and negative for non-innovating firms.

Despite its restricted scope in terms of number of companies and variables included, these results are interesting, if only because they fit into a not particularly large set of empirical studies on the determinants of innovation and the effects of external sourcing in developing countries such as Tunisia. They clearly demonstrate 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 positive 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 the kind of public subsidies should be chosen according to the in-house R&D effort. Some incentives mechanisms can be instituted 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 of 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.

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Table 1: Distribution of Innovating Firms According to Branch Activities

Activities	% of firms	% of innovative firms in each sector
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 & 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

Table 2: Estimation of Product Innovation Probability

Variables	Dichotomic Probit (1)		Heckman-Lee (H-L) (2)	
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	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%.

Table 3: Estimation of R&D Investment Function Heckman Selection Model (regression model with selection correction)

Variables	**All firms (1) GLS**		**Innovating firms (2) H-L**		**Non-innovating firms (3) H-L**	
Size (Turnover e-07)	0.00353	(0.02153)	0.06539*	(0.03925)	0.00040	(0.05093)
Size (logTurnover)	4.30073***	(0.46083)	2.970***	(0.63617)	3.15047***	(0.9347)
Membership of Group	0. 03279*	(0. 02033)	0. 04624**	(0. 02399)	0. 03088	(0. 04856)
Human capital	0.01614**	(0.00571)	-0. 00529	(0.00932)	0. 01575*	(0.00967)
Foreign capital	-0.05061***	(0.01304)	-0.0285	(0.02477)	0.08776***	(0.02057)
Public capital	2.66744***	(0.49950)	2.15251***	(0.62037)	0.80095	(0.90922)
Partnerships	2.98498***	(0.52568)	3.22878***	(0.60025)	-0.41596	(2.3618)
Buy-NEM	1.52568**	(0.68941)	1.47021**	(0.67291)	-	
Buy-RNT	3.7309***	(0.51936)	2.8512***	(0.60926)	-3.38832***	(0.86135)
Buy-NTP	1.27038**	(0.56628)	0.93385	(0.67437)	1.36865	(1.00281)
Change-ORG	0.03522	(1.11132)	0.90986	(1.33059)	-3.2656	(3.60793)
Spillover*e-07[1]	0.23063***	(0.04446)	0.18727***	(0.05203)	0.04593	(0.07696)
Spillover–depar.*e-07[2]	-0.22268***	(0.08151)	-0.18049**	(0.08458)	-0.09437	(0.2268)
Spillover - department[3]	6.73564***	(2.22839)	6.34653***	(2.5129)	-2.2726	(5.30476)
Market share	2.23481**	(0.95199)	2.0952	(1.6156)	-0.81933	(3.42719)
Rho			-0.92200***	(0.04109)		
Lambda			-2.9771***	(0.28728)	0.4704	(0.92577)
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***			
R-squared	0.8333		-		-	

The numbers between () are the estimated standard deviation.
(***) Significant at 1 %, (**) Significant at 5 %, (*) Significant at 10 %.

[1] The first term of spillover which refer to the effect of external R&D $\left(m_1 \sum_{j \neq i} RD_{js} \right)$

[2] The second term of spillover which refer to the interaction between external R&D and a firm's own R&D department $\left(m_2 \sum_{j \neq i} RD_{js} \left(RDDEP_i \right) \right)$

[3] The second term of spillover which introduce the interaction between external R&D and firm's own R&D department $\left(m_2 \sum_{j \neq i} RD_{js} \left(RDDEP_i \right) \right)$

Appendix 1

Table 4: R&D Investment Estimation According to the Innovation Regimes

Variables	*Innovating firms*		*Non-innovating firms*	
	GLS		***GLS***	
Constant	9.0741***	(0.53329)	9.5649***	(.8351)
Size (log 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)
	0.00147	(0.01989)	0.06919***	(0.02017)
Public capital	3.78154***	(0.57553)	2.24158	(3.61045)
Buy-NEM	1.89797***	(0.68806)	-	
Buy-RNT	3.30109***	(0.65056)	4.88211***	(0.90194)
Buy-NTP	0.81513	(0.71135)	1.48903	(1.25597)
Change-ORG	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)
Spillover-department	7.90097***	(2.28272)	2.07885	(3.88448)
Market share	2.809**	(1.1515)	1.0778	(1.7574)
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: Heteroscedasticity Test

```
. reg ldep_tot_04 chiffre_affaires_2004   p_participation_prives_etrangere   appartient_groupe total_effectif partenar
> d111 d114 d201 d202 e6pc rd_sec1 spill_c ca_relat if(innovation_d11)

      Source |       SS       df       MS              Number of obs =     206
-------------+------------------------------           F( 13,   192) =    3.02
       Model |  297.978361    13  22.9214124           Prob > F      =  0.0005
    Residual |  1455.57284   192  7.58110852           R-squared     =  0.1699
-------------+------------------------------           Adj R-squared =  0.1137
       Total |   1753.5512   205  8.55390828           Root MSE      =  2.7534

------------------------------------------------------------------------------
 ldep_tot_04 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
chiffre~2004 |   2.54e-09   1.78e-09     1.43   0.155    -9.74e-10    6.06e-09
p_partici~re |  -.0028601   .0054796    -0.52   0.602     -.013668    .0079479
appartient~e |   .4744119   .4033005     1.18   0.241    -.3210567     1.26988
total_effe~f |   .0249363   .0157213     1.59   0.114    -.0060724    .0559449
    partenar |  -.2142308   .4078415    -0.53   0.600    -1.018656    .5901944
        d111 |   .5892502   .4144726     1.42   0.157    -.2282541    1.406754
        d114 |   .9662544   .4415984     2.19   0.030     .0952474    1.837261
        d201 |   1.173839   .4043727     2.90   0.004     .3762552    1.971422
        d202 |   .6097316   .4396214     1.39   0.167    -.2573762    1.476839
        e6pc |   .7723623   .8588371     0.90   0.370     -.921605    2.466329
     rd_sec1 |   3.80e-09   3.47e-09     1.10   0.274    -3.04e-09    1.07e-08
     spill_c |  -5.35e-09   5.58e-09    -0.96   0.339    -1.64e-08    5.66e-09
    ca_relat |   2.809249    1.78059     1.58   0.116    -.7027807    6.321279
       _cons |   9.074153   .4916149    18.46   0.000     8.104493    10.04381
------------------------------------------------------------------------------

. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ldep_tot_04

         chi2(1)      =    14.63
         Prob > chi2  =   0.0001
```

```
. reg ldep_tot_04 chiffre_affaires_2004   p_participation_prives_etrangere   appartient_groupe total_effectif partenar
> d111 d114 d201 d202 e6pc rd_sec1 spill_c ca_relat if(1-innovation_d11)

      Source |       SS       df       MS              Number of obs =      94
-------------+------------------------------           F( 12,    81) =    2.21
       Model |  272.149348    12  22.6791123           Prob > F      =  0.0184
    Residual |  830.870302    81   10.257658           R-squared     =  0.2467
-------------+------------------------------           Adj R-squared =  0.1351
       Total |  1103.01965    93  11.8604263           Root MSE      =  3.2028

------------------------------------------------------------------------------
 ldep_tot_04 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
chiffre~2004 |   2.92e-09   3.54e-09     0.83   0.411    -4.11e-09    9.96e-09
p_partici~re |  -.0244532   .0086602    -2.82   0.006    -.0416842   -.0072222
appartient~e |    .555098   .7498359     0.74   0.461    -.9368401    2.047036
total_effe~f |   .0542171   .0418905     1.29   0.199    -.0291319    .1375661
    partenar |  -.0660396    .788663    -0.08   0.933    -1.635232    1.503152
        d111 |  -1.017076   2.070023    -0.49   0.625    -5.135773    3.101621
        d114 |  (dropped)
        d201 |   1.720573   .7398405     2.33   0.023     .2485227    3.192624
        d202 |   1.336407   .8452473     1.58   0.118    -.3453699    3.018184
        e6pc |   -1.55253   3.351324    -0.46   0.644    -8.220613    5.115553
     rd_sec1 |   1.03e-09   6.45e-09     0.16   0.873    -1.18e-08    1.39e-08
     spill_c |  -1.23e-08   1.60e-08    -0.77   0.444    -4.42e-08    1.96e-08
    ca_relat |   1.077827   3.330685     0.32   0.747    -5.549191    7.704844
       _cons |   9.564904   .8741233    10.94   0.000     7.825673    11.30414
------------------------------------------------------------------------------

. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ldep_tot_04

         chi2(1)      =    17.38
         Prob > chi2  =   0.0000
```

Appendix 3: Equality Tests of the Average Investments in R&D

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

```
. ttest rd_inno=rd_non, unpaired unequal

Two-sample t test with unequal variances
```

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
rd_inno	206	11.02967	.0840005	1.205634	10.86406	11.19529
rd_non	94	10.13978	.1764405	1.710654	9.789402	10.49015
combined	300	10.75084	.0832213	1.441435	10.58706	10.91461
diff		.8898935	.1954158		.5034659	1.276321

```
    diff = mean( rd_inno) - mean( rd_non)                     t =   4.5538
Ho: diff = 0                     Satterthwaite's degrees of freedom =  136.749

    Ha: diff < 0                Ha: diff != 0                Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

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

```
. ttest  lrd_inno = lrd_non, unpaired unequal

Two-sample t test with unequal variances
```

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
lrd_inno	220	10.9467	.1993182	2.956367	10.55388	11.33953
lrd_non	101	9.958457	.3608775	3.626774	9.242487	10.67443
combined	321	10.63576	.1791572	3.209865	10.28328	10.98823
diff		.9882451	.4122624		.1741956	1.802295

```
    diff = mean( lrd_inno) - mean( lrd_non)                   t =   2.3971
Ho: diff = 0                     Satterthwaite's degrees of freedom =  163.374

    Ha: diff < 0                Ha: diff != 0                Ha: diff > 0
 Pr(T < t) = 0.9912         Pr(|T| > |t|) = 0.0177          Pr(T > t) = 0.0088
```