The location decision of innovative technological intensive firms. The importance of universities ♣

Joana Costa (030411020@fep.up.pt) [a] and Aurora A. C. Teixeira (ateixeira@fep.up.pt) [b,]

[a] *Faculdade de Economia, Universidade do Porto, Portugal*

[b] *CEMPRE, Faculdade de Economia, Universidade do Porto, Portugal*

Abstract

Within a debatable framework of 'natural replication' of well-succeeded cases such as the Silicon Valley, Route 128, OECD countries have been implementing policy measures directed to the stimulation of the development of regional clusters composed by Technology-Intensive Firms (TIF) around universities believing that this would increase economic returns from public research investment thereby fostering regional economic development. This investigation tries an empirical answer to the following questions: 1) Are universities important as source of information and knowledge use for TIF innovation activities?; 2) How relevant are universities for the location decisions of TIF?; Is TIF's human capital composition a relevant variable for strengthening university-TIF linkages and thus contributing for enhancing regional innovation capabilities? Based on survey data of 425 Portuguese TIF we conclude that university is critical to these firms innovative activities being therefore likely to substantially and positively impact on regional knowledge network flows and density. The evidence collected shows therefore an unequivocal support for public policies measures targeting TIF as innovation leverages and regional boosters.

Key words: technology based firms, universities linkages, Portugal

JEL-Codes: O31; O32; O38; C25

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1. Introduction

Within a debatable framework of 'natural replication' of well-succeeded cases such as the Silicon Valley, Route 128, OECD countries have been in recent years implementing policy measures directed to the stimulation of the development of regional clusters composed by Technology Intensive Firms (TIF) and more specifically New Technology Intensive Firms (NTIF), around Universities believing that this would increase economic returns from public research investment thereby fostering regional economic development. In sequence, strong university-TIF linkages and the creation of spin-off firms based upon university-developed technologies would be expected to emerge (OECD, 2002).

Since the 70s governments throughout the industrialized world are trying to proximate universities from firms, namely (N)TIF, with the belief that this relationship would encourage local economic development (OECD, 1996). In this approach, universities are considered as instruments of knowledge-based economic development and change (Mowery and Sampat, 2004). Specifically, governments of most OECD countries support interactions between universities and industry in the belief that this interaction can increase the rate of innovation in the economy (Spencer, 2001). Thus, the creation of science parks, the support of business incubators, seed capital, specific supports for the development of joint R&D projects are examples of policy efforts to link universities to industrial innovation.

Evidence, mainly based on data of the Community Innovation Survey (CIS), suggests that universities rarely act as direct source of information or knowledge for the innovation activities of European firms. It is important to note that these rather detailed and comprehensive studies embraces all types of firms, both technology based and non-technology based firms. In this way, their broad conclusions cannot directly guide policy-related measures, which tend to be focused on more technology or knowledge intensive firms.

Moreover, the regional dimension, which is a fundamental pillar of public support measures related to the link between universities and firms, is often neglected by innovation-led studies. Studies that focused this latter dimension try to explore the importance of universities as determinant for firms' location choices without, however, putting much emphasis on the relevance of universities as potential sources of knowledge and ideas for firms' innovation activities.

Another dimension, which has been seldom tackled, is the human capital composition and endowments of TIF and the role that it potentially plays in intermediating universities-firm linkages.

In the Portuguese case, such type of evidence is relatively sparse. Some pioneering works concerning the role of the (N)TIF are from Fontes and Coombs (1995, 2001). These studies show that these firms have performed a critical role contributing for the strengthening of indigenous capability. Nevertheless, the number of firms involved in these studies is rather small (28), hampering a more generalised study of Portuguese TIF. Moreover, albeit acknowledging the importance of university linkages as a way to compensate firms' weaknesses, they do not focus on universities as potential sources of knowledge for innovative activities.

The present study attempts at complement those above-mentioned studies by assessing the importance of universities as source of information and knowledge use for TIF and analysing the importance of university proximity and firms human capital endowments. Adding to the few studies existing for the Portuguese economy, we endeavour at drawing some policy implication on the role of university-TIF linkages for innovation and regional development.

Specifically, this investigation tries to answer the following questions: 1) Are universities important as source of information and knowledge use for TIF innovation activities?; 2) How relevant is university proximity for TIF draw from universities?; Is TIF's human capital composition a relevant variable for strengthening university-TIF linkages and thus contributing for enhancing regional innovation capabilities?

We try to answer these questions through a direct inquiry to all (707) the Portuguese TIF that reported having performed R&D activities in 2001-2003. Using ordered logit models we analyse the 425 respondent TIF and discuss the main hypothesis put forward.

The paper is structured as follows. In Section 2, we briefly portrait review the literature on the link between universities and firms, highlighting the main theoretical approaches in the area and potential gaps to be fill, linking these with the main hypothesis of the present study. In the following section, we present the data collecting methodology and some exploratory results from the survey performed. Section 4 details the results of the empirical work and discusses the main hypotheses. Finally, in Conclusion we systematise the main outcomes of the investigation.

2. On the link between universities and firms. A theoretical review

2.1. Innovation-related literature

National innovation systems are composed by institutions and actors that affect the creation, development and diffusion of innovations. Firms, Universities and Government institutions, are the principal vehicles through which technological advance proceeds (Edquist, 1997).

The links between science and technology are complex and vary from field to field, new science gives rise to new technology. Technology advances are mostly due to individuals who have university training in science of engineering. This is the main reason why, in many fields, university research is an important contributor to technical advance, and universities as well as corporate labs are essential parts of the innovation system (Nelson, 1993; Edquist, 1997).

Universities are capital agents of technical advance, not only as scientists and engineers trainers but as source of research findings and techniques. Their research produces different outputs: information (both scientific and technological), equipment and instrumentation, competence building, scientific networks and prototypes (Freeman, 1982).

Direct effects of universities on industrial innovation have been difficult to empirically prove due to the complexity of the relation established, which is mediated by a complex set of institutions and overlapping interactions (Salter and Martin, 2001).

We can find different theoretical frameworks such as the “National Systems” (Nelson, 1993), “Mode 2” (Gibbons et al., 1994) or the “Triple Helix” (Etzkowitz and Leytesdorff, 1997; 2000) conceptualising the role of research universities within innovation processes of knowledge-based economies. The “Triple Helix” thesis states that universities can play an enhanced role in innovation. In national system of innovation the firms have leading role conducting innovation processes. “Mode 2” framework permits to understand the role of academic research in modern societies. Standing on the increased needs of scientific research they point to a more interdisciplinary, pluralistic and networked innovation system where the research institutions (corporate and academic) are more involved with other actors. They underline that the diversification of the actors involved in the innovative process is not synonymous of a decline of the importance of the Universities as research centres.

Summing up, these different frameworks transversally considered underline the existence of strong links between universities and other institutional actors.

Universities accomplish different functions (e.g., teaching, research, product development, consultancy), involving knowledge creation and diffusion (Nelson, 1993; Gibbons et al., 1994; Edquist, 1997). Cross-country evidence analysed by Mowery and Sampat (2004) shows that despite accomplishing similar functions in most industrialized countries, university's importance in research performance and competence building considerably vary. The differences reflect different industry structures, different relative importance of high-tech sectors and different non-university research institutions. Firms can benefit from University interactions in different ways (Schartinger *et al.*, 2001). Diverse bibliometric studies (Hicks and Hamilton, 1999; Laredo and Mustar, 2001; Calvert and Patel, 2002) reveal that cooperation between Universities and industry is increasing and expanding to multiple areas and forms providing empirical support for the different frameworks of interaction.

According to Laursen and Salter (2004: 1203), "… attempts to examine university–industry linkages have tended to focus on the role of "structural factors", such as size, industrial context and R&D expenditures in shaping the use of universities by industrial firms. Most of this research is conducted by economists and in their models, they provide little scope for managerial choice and for firm strategy." Albeit most recent efforts in this domain, led by Laursen and Salter (2004), overcome the limitations of 'structural' perspectives, they tend to neglect some dimensions that are fundamental concerns when public support measures are put forward. In fact, most of government related policies concerning the links between universities and firms explicitly focus on (N)TIF and put the regional (location) and workforce (human capital) improvement concerns as end-goals of such policies.

2.2. Location-related literature

There exists a growing literature, which gathers empirical evidence supporting the existence of knowledge externalities in regions surrounding research universities (Acs et al., 1992; Jaffe et al., 1993; Anselin et al., 2000; Woodward et al., 2003). In turn, studies that analyse more deeply that link from a point of view of location patterns (Acs et al., 1994; Henderson et al., 1998; Jaffe, 1989) try to explore the importance of universities as determinant for firms' location choices. They, however, do not put much explicit emphasis on the relevance of universities as potential sources of knowledge and ideas for firms' innovation activities.

Traditional urban and regional theories (von Thünen, 1826; Weber, 1929; Hoover, 1948; Lösch, 1954) explore location decisions emphasising factor costs and demand (encompassing factors such as labour costs, land costs, taxes, market size). However, it is commonly accepted that these traditional determinants should be considered along with factors such as agglomeration (both location and urbanisation) economies, where universities seems to have an important role (Mowery and Sampat, 2004).

Broad empirical evidence (e.g., Markusen et al., 1986; Florax, 1992) discloses that the presence of R&D activities, the capacity of knowledge creation and technological innovation are factors that condition the "configuration" of the regional and local economies. In concrete, we find in literature a set of works that highlights the role of universities underlying its contribution for the existence of a high-skilled labour market as well as for the production and diffusion of knowledge (Saxenian, 1985, Malecki, 1985; Markusen et al., 1986; Florax, 1992; Huffman and Quigley, 2002; Woodward et al., 2003).

In fact, we can easily accept that technological innovation produced in a given region results, to a large extent, from well structured networks of firms-academic and other institutions, which are in permanent interaction (Stohr, 1986; Von Hippel, 1988, Storper and Walker, 1989). The production of basic knowledge as well as technician formation fits well into universities functions, contributing therefore to the adoption and creation of new technologies, maintaining the innovation circle dynamics.

The cooperation in the R&D processes constitutes a formal and lasting way to implement in firms the knowledge produced in the university laboratories (Audretsch and Feldman 1996; National Science Board, 1982; Wilson, 1979). University consultancy activities constitute also alternative collaboration forms, though weaker and more sporadic (National Science Board, 1982). Although constituting a more impersonal way of knowledge transfer, firms might also draw from knowledge developed in universities by reading scientific publications produced by them. The strongest linkage that might connect firms and universities is the one that is established though specialised labour force mobility, technicians training and the supply of high quality scientists and engineers (National Science Board, 1982).

The evidence allows asserting that the level of labour qualifications, the implemented technology and the innovation capability constitute critical factors of productivity levels. From this it is possible to infer that universities tend to be an important leverage of productivity (National Science Board, 1982; Wilson, 1979) at firm and regional levels.

Summing up, the strategic role of universities is rooted in two vectors, production of high quality human capital and knowledge externalities, both of them determinant factors for attracting firms (Malecki, 1985), and therefore act as “regional machines of knowledge” or “regional boosters” (Florax, 1992).

In the present work, instead of focusing on the university as location determinant per se, we are interested in investigating a less explored issue, the influence of university proximity on the propensity of TIF drawing from universities in their innovative activities.

2.3. The relevance of human capital

The relevance of human capital to technological competence and development seems to be universally accepted in the literature, though empirically the evidence has produced mixed results. According to Schultz (1961), human capital investments, namely expenditure in formal education and training, explain the superiority in production of the technically advanced countries. Formal education, largely through the provision of literacy, numeracy, and general education, is likely to generate a basic ‘ability to learn’ that is vital in the innovation process (Foster, 1987) and may provide vicarious experience of a broader world than the individual can personally encounter thus, presenting to the mind alternatives of environment and of policy and suggesting opportunities for progress, but also hazards against which protection is required (Hirshleifer, 1966).

An important aspect that comes up from the studies surveyed is an increasing recognition that with new technology employers may need to retain the skills of at least *some* workers (Bosworth et al., 1992).[1] In an environment characterised by rapid technological change, several authors emphasise the role of top educated and top skilled workers.

In one of the first micro-studies which related human capital and technological issues, Layard et al. (1971) point out that, in industries where technical progress is rapid, firms lose their markets unless they innovate and therefore they demand qualified personnel.

[1] For more detailed information on the link between human capital and firm performance, see Teixeira (2002).

A similar argument is stressed by Whiston et al. (1980). According to these authors many highly trained and educated people may be needed to change the design of products, processes and organisations in an environment of rapid technological change. In this context, the argument goes, a shortage of skilled people (in particular, engineers and scientists) can result in a failure to develop, or delay in developing, the planned products and the production processes by which they are to be made (Senker and Brady, 1989). In the same line, other authors (Welch, 1970; Bartel and Lichtenberg, 1987; Gill, 1989; Booth and Snower, 1996) argue that in a dynamic context, educated persons can take more advantage of available technology and thus be more productive. In fact, high levels of education may interact with technological progress on at least two levels (Rebelo, 1994): firstly, highly skilled individuals, who have undergone long periods of formal schooling, are responsible for the vast majority of innovations; secondly, the effective use of new technologies often requires high levels of human capital.[2]

Empirically, some authors (Bartel and Lichtenberg, 1987; Wozniak, 1987; Steedman and Wagner, 1989; Senker and Senker, 1994; Rios-Rull et al., 1996) have proved that the incentives to invest in technology and particularly in research and development and human capital are interdependent. Using case study material Senker and Brady (1989) argued how important it is for firms to complement their processes of technological development with appropriate human resource development strategies.

Austrian evidence studied by Schartinger et al. (2001) shows that the main knowledge-transferring channel between universities and firms is the mobility of human capital. Education constitutes, therefore a source of information (Gibbons and Johnston, 1974), which tends to be highly relevant to ‘decode’ new technical information (Lall et al., 1993), and to incorporate it into manufacturing process.

University education is, according to Gibbons and Johnston (1974), crucial for “problem solvers”, as it imparts a more general capability to assess the adequacy of knowledge for the resolution of a problem and to initiate a search to obtain further relevant information (“knowledge of knowledge”). The more educated a manager is, the quicker he/she will be to introduce new techniques of production; additionally, he/she is likely to adopt productive innovation earlier because his/her ability to understand and evaluate the information on new products and processes is higher; moreover, he/she

[2] Pack (1974) points out that lower efficiency in less developed countries in a given industry would not necessarily imply technical inferiority of older equipment, rather such differential efficiency could result from organisational and motivational factors or human skill differentials that are unrelated to equipment characteristics.

tends to be quicker to adopt profitable new processes and products because the expected payoff from innovations is likely to be greater and the risk smaller. In other words, such a manager is better able to discriminate between promising and unpromising ideas and less likely to make mistakes (Nelson and Phelps, 1966).

Thus, a study on the propensity of TIF to draw from universities should include the firms' human capital composition as a fundamental intermediating variable.

2.4. Main hypothesis to be tested

We aim at understanding the importance of universities as sources of knowledge information for TIF innovative activities seeking as well to assess the influence of university proximity and firms' human capital composition on the perception that TIF have concerning the importance of universities in this domain. The issue is therefore University-TIF linkages.

Our main research questions are: how important are universities as a source of information and knowledge in comparison to other possible sources of innovation for Portuguese TIF; how relevant is university proximity for TIF draw from universities, and is TIF's human capital composition a relevant variable for strengthening university-TIF linkages and thus contributing for enhancing regional innovation capabilities.

To our knowledge no study exists for Portugal aiming at empirically testing the link between TIF and universities, in particular TIF's search strategy using universities in their innovative activities.

Laursen and Salter's (2004) study presents a well-systematized set of hypothesis respecting the link between firms and universities. Here we 'stand on the shoulders of giants' departing from their framework and adding two extra hypothesis, one concerning location-related impact and other firms' human capital intensity.

The literature refers to some 'structural' variables as possible factors influencing the propensity of a firm to draw from universities, namely size, age, and R&D intensity.

Cohen et al. (2002) and Salter and Martin (2001) empirically prove that size positively influences the propensity to refer Universities as source of innovation. In the same line, Link and Rees (1990), Arundel and Geuna (2000), Mohnen and Hoareau (2003), and Laursen and Salter (2004) find that firm size has a positive impact on university – industry links. Moreover, Schartinger et al. (2001) refer that the R&D department size influences the university relationship, firms with big departments, despite being less flexible, are more likely to engage important research projects.

Achieving, at the first glance, different results from the above studies, Acs et al. (1994) find that small firms benefit more from university spillovers than larger. This evidence makes us believe that they are more likely to draw upon Universities, so size might be negatively related to the propensity of a firm to draw from universities. Related evidence gathered by Acs and Audretsch (1987a; 1987b; 1988) and Pavitt (1987) corroborates the fact that small firms are more innovative than larger ones, presenting higher innovation rates and patents per technical employee. Bommer and Jalajas (2004) also argue that small firms are more dynamic.

Therefore, the relation between firm size and its ability to draw from University seems to be ambiguous. In our case, we want specifically to assess whether size matter for TIF and University linkages. That is, whether larger TIF are likely able to devote more resources (physical and human) to innovative activities than their lower size counterparts, consequently uplifting their propensity for drawing from University.

Hypothesis 1: Larger TIF are more likely to draw from universities

Concerning firm age, Schartiger (2001) refers that the a priori effect is unclear. NTIF are highly technology dependent and are more permeable to knowledge acquiring whereas old TIF are more probable to get high knowledge stocks (in vast fields) during their lifetime being for consequence less university dependent. Notwithstanding, during their lives old firms are more likely to have established solid relationships with Universities and consequently elevate the probability to interact. Additional evidence does not help to provide clearer answers. Cohen et al. (2002), focusing on the use of university knowledge in R&D labs, suggest that start-ups are more likely to draw from universities; instead, Laursen and Salter (2004), using a large-scale database, fail to get statistical significance for the age variable.

Hypothesis 2: Age negatively influences drawing from universities

R&D intensity is another ‘structural’ variable that has received a lot of attention by the literature. Scientific and technological capabilities of firms are commonly measured using R&D expenditures (Markusen et al., 1986). Cohen and Levinthal (1989) suggest that scientific and technological capabilities of firms positively influence the use of public research. R&D expenditures enable firms to develop new products and processes, and, simultaneously simplify the process of knowledge absorption from the evolving environment; thus, absorptive capacity tends to depend on R&D intensity (Cohen and Levinthal, 1990).

In a small number of sectors, university is conceived as critical to industrial R&D, nevertheless Cohen et al. (2002) argue that a big part of the manufacturing sector is strongly affected by industrial R&D. Klevorick et al. (1995) recall that there exists, however considerable variation upon different sectors concerning the propensity of drawing from Universities.

The empirical evidence on this issue is (similar to the above) troublesome. Whereas Cohen and Levinthal (1990) argue that R&D expenditures positively influence the importance of Universities as innovation source, Salter and Martin (2001) finds no evidence of the relevance of R&D expenditures. It is important to note, however that the most recent evidence (Mohnen and Hoareau, 2003; Laursen and Salter, 2004) supports the importance of R&D intensity. Thus, in the line of such latter evidence one can expect that the level of R&D intensity will positively influence the relying upon Universities.

Hypothesis 3: R&D intensity positively influences drawing from universities

Several authors (e.g., von Hippel, 1998) refer that firms' innovation activities are strongly determined by their relations with suppliers and customers. Indeed, other sources of information and knowledge, besides Universities seem to be quite significant. For instance, Germunden et al. (1992) and Salter and Martin (2001) point customers as important sources of successful new product ideas.

According to Laursen and Salter (2004), several studies have found that search strategies play a central role in determining innovative performance (e.g., Katila and Ahuja, 2002). These authors provide a proxy for assessing the degree to which the firm seeks to draw in new knowledge and to re-use (that is, openness of a firm's search activities). The constructed variable is based on the number of different sources of external knowledge that each firm draws upon in its innovative activities. Implicitly, it is assumed that the higher the number of external knowledge sources that a firm draws upon the more "open" it is its search strategy. With this variable the authors seek to introduce a degree of managerial choice into the debate about university–industry links.

Our inquiry enables testing Laursen and Salter's 'openness' hypothesis as TIF were asked to refer the importance of sixteen different external knowledge sources (including universities).

Hypothesis 4: "Openness" positively influences drawing from universities

As reviewed above, several studies draw attention to the role of universities in the supply of high-skilled workforce and the production and diffusion of knowledge

(Malecki, 1985; Saxenian, 1985; Markusen et al., 1986; Florax, 1992; Huffman and Quigley, 2002; Woodward et al., 2003). In fact, the production of basic knowledge as well as technician formation fits well into universities functions, contributing therefore to the adoption and creation of new technologies.

Thus, we might expect that TIF that are geographically closer to universities are more likely to draw from them in their innovative activities.

Hypothesis 5: Geographical proximity positively influences drawing from universities

Albeit the above-mentioned factors were already reasonably focused by the literature, a rather neglected aspect is the influence of human capital composition and endowments on the propensity of TIF to draw from Universities. In this paper we aim at contributing to fill this gap by investigating the importance of this factor.

As surveyed in Section 2.3, there is an increasing recognition that (N)TIF may need to retain the skills of at least *some* workers (Bosworth et al., 1992). In an environment characterized by rapid technological change, several authors emphasize the role of top educated and top skilled workers. University education is, according to Gibbons and Johnston (1974) crucial for "problem solvers", as it imparts a more general capability to assess the adequacy of knowledge for the resolution of a problem and to initiate a search to obtain further relevant information ("knowledge of knowledge"). Therefore, we would expect that relatively more human capital endowed TIF would be more likely to draw from universities in their innovative activities.

Hypothesis 6: Human capital intensity positively influences drawing from universities

3. Data colleting methodology and exploratory results

3.1. Representativeness of the respondent sample

The data for the analysis is drawn from the Markelink 2004 list, which comprises Portuguese firms that declared and publicised R&D activities.[3] The only information that this source provides is the name of the firm. Nevertheless, to our knowledge, apart from CIS and Observatório para a Ciência e Ensino Superior (OCES) R&D surveys, this is the most comprehensive and up to date list of Portuguese innovative or TIF (i.e., those with R&D activities) which is freely available.

The Third Community Innovation Survey (CIS III) for Portugal, implemented in 2001-2002, analyses 1875 firms with ten or more workers and shows that around 830 firms

[3] Markelink is a private information supplier who manages several database concerning a broad set of issues, including R&D (http://www.markelink.com/).

were ‘innovative’ (Bóia, 2003). In this survey, firms are considered ‘innovative’ if they have introduced in a reference period of time market products or processes, which are new or significantly improved in the context of the firm.

OCES survey tries to assess Portuguese firms’ innovation potential. This inquiry is conducted, every two years, and focus specifically R&D indicators.[4] In the most recent report, respecting the year of 2001 (and published in 2003), it is argued that out of a universe of 2130 respondent firms potentially performing R&D activities there were only 568 ‘innovative’ firms, that is, firms that performed R&D activities.

Given that the firms database underlying CIS and OCES surveys are not of public domain and that the number of firms included in Markelink’s list is 703, representing 85% of CIS III ‘innovative’ firms and encompassing a much higher number of firms than those considered as ‘innovative’ by the last OCES survey, we decided to consider this latter database as our base for inquiry.[5] It is important to note that, similarly to CIS and OCES, Markelink list encompasses firms from all industry scope located within the Portuguese territory (including Açores and Madeira islands), and differently from CIS covers all size classes.

The survey was implemented in November-December 2004 and the inquiry was sent to all the firms contained in the Markelink list (703) plus 4 firms that we knew through the available on-line OCES’ list of Portuguese firms with the largest R&D expenditures in 2001[6] that performed R&D activities and were out of Markelink list. In a first stage, the inquiry was sent by e-mail, but taken the delivering difficulties we opt to send them by fax. With this method we managed to have only 25 responses. In a second stage, we decided to make direct phone calls followed by sending again the inquiry by fax. By the middle of December, 425 complete valid questionnaires were received, which represents an effective response rate of almost 61%.[7] This is a surprisingly high response rate for a non-official inquiry. For instance, in the CIS III inquiry, which is compulsory, the response rate was 45.8% in the case of Portugal (Bóia, 2003), and 41.7% for the U.K. (Stockdale, 2002).

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[4] ‘IPCTN 2001 - Inquérito ao Potencial Científico e Tecnológico Nacional 2001’, published in 2003.

[5] Please note that as we do not have information on which particular firms are in the CIS III and OCES databases, we cannot guarantee that firms in Markelink database constitute a common set to those in the previous databases.

[6] http://www3.oces.mces.pt/relat_popup.php?id_item=50636&pasta=9 (accessed on 1st December 2004).

[7] The total population considered here is not the 707 firms but 697 because it was impossible to send the fax to 10 of them.

Using a formula for computing the size of the sample, in random samples, based on a pessimistic scenario (Vicente et al., 1996), a sample size of 425 observations (in a population of 697 firms) would lead, for a confidence level of 95%, to a precision of approximately 0.03.[8]

In the next table the main characteristics (industry and location distribution) of the respondent firms is assessed and compared to the population.[9]

Table 1: Characteristics of the respondent Portuguese technology based firms – sector and location distribution (in %) compared to the population, 2001-2003

	Population (n=698)*	Respondent sample (n=425)
Industry		
Agriculture, fishery and extractive industry	5,6	3,8
Food, drink and tobacco	4,9	5,6
Textiles	5,1	8,7
Wood, paper and printing	3,8	3,8
Chemicals and plastics	8,2	11,8
Non-metallic minerals	3,3	4,5
Basic metals and fabric metal products	4,8	7,3
Machinery	5,9	8,7
Electrical	9,3	7,3
Transport and other manuf.	11,6	5,6
Utilities and construction	2,0	2,8
Retail and Wholesale	8,9	7,8
Computing, R&D and firm services	18,2	16,9
Other services	8,3	5,4
Location (NUT II)		
Norte	35,2	38,4
Centro	17,0	21,9
Lisboa e Vale do Tejo	42,5	35,8
Alentejo	2,7	2,1
Algarve	1,7	0,7
Madeira e Açores	0,9	1,2

Source: Authors' computation based on direct survey, November-December 2004.
Notes: * Concerning SIC-codes and location for the population as it stands Markelink list in we only were able to find, respectively 610 and 664 firms with valid information (recall that the original database only provides the name of the firms).

[8] Considering, *N* the population size, *n* the sample size; *p* the proportion of elements in the sample that possess a given characteristic; *B*, the precision level; *Z* =1,96, the coefficient associated to a level of confidence of 95%. In a pessimistic scenario, i.e., in a scenario where the sample variance is maximum, *p*=0.5.

[9] As the only information that we have from Markelink list was firms' name, the industry and location information was gathered by searching the internet, yellow pages, Telelista and the National Register of Collective Entities.

In Table 1 the main characteristics (industry and location distribution) of the respondent firms is assessed and compared to the population.[10]

Compared to the whole population of TIFs, the respondent sample seems to be biased towards ‘Textiles’, ‘Basic metals and fabric metal products’ and ‘Machinery’ industry, and underrepresented for ‘Transport and other manufacturing’, ‘Other services’ and ‘Agriculture, fishery and extractive industry’.

It is interesting, however, to note that in the most knowledge intensive industries (‘Electrical’ and ‘Computing, R&D and firm services’), the respondent sample is quite representative of the whole population.

Regarding to location distribution, Madeira and the Azores come up over-represented in comparison to the whole population, whereas the Algarve and Center are under-represented. In the remaining NUTs, the representativeness is reasonable.[11]

3.2. Exploratory results

As said above, we intend to investigate the knowledge sources for innovation and the location patterns of technology based firms in Portugal, focusing on industry-university relations.

Our main research questions are how important are universities as a source of information and knowledge in comparison to other possible sources of innovation for Portuguese technology based firms, and how universities proximity and TIF human capital composition might influence these firms’ perception on university importance at this level.

Concerning knowledge or information sources for TIFs innovative activities, we use a broad scale, 0–1–2–3–4–5, with 0 indicating that the firm does not use the listed source. Table 2 lists seventeen innovation-related knowledge sources. Using category groups that are comparable to Laursen and Salter’s (2004), the information and knowledge sources for innovation activities were assembly into six different items (internal, institutional, market - business networks, sector information, specialized information and other). The distribution of firms (in percentage of the total number), according to the importance that they attributed to the listed sources is presented in Table 2.

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[10] As the only information provided by the Markelink list was the firms’ name, the industry and location information was gathered by searching the internet, yellow pages, Telelista and the National Register of Collective Entities.

[11] We do not assess the representativeness of our sample concerning firm size because the underlying population list does not provide information in this regard.

The number of TIFs which claim to draw from Universities in their innovative activities is quite high (88.2%). Nevertheless, it is still well below the scores for “business-networks” and “sector and specialized information” sources. Despite this high percentage of firms, ‘only’ 42.8% of TIFs located in Portugal indicate that the knowledge they draw from Universities is highly important. Next, ‘Internal’, with 88.9%, and ‘Technical standards norms’, ‘Technical and sector literature’ and ‘Clients’, are the sources considered as highly important for more than seventy per cent of the respondent TIFs.

The results obtained here contrast substantially with the CIS III inquiry to Portuguese firms. In the latter, Universities and other higher education institutions presented a score below 5% in what concerns the proportion of firms which claimed that these institutions were a highly relevant source of information for innovation. It is important to note, however, that the CIS covers all types of firms whereas our set involves only TIFs. In this regard, the fact our firms present a higher score in this item comes as no surprise although the magnitude of the score can be viewed as remarkably high by Portuguese standards.

Table 2: Innovation-related information and knowledge sources for Portuguese technology based firms, 2001-2003 (n=425)

Type	Source	% of firms			
		Not used	Low or very low	Medium	High and very high
Internal	Within the firm	0,5	1,4	9,2	88,9
Institutional	Universities	11,8	21,1	24,3	42,8
	Public R&D institutes	16,3	21,3	32,3	30,2
	Other governmental entities	17,5	29,5	34,0	19,1
	Private R&D institutes	32,6	21,7	22,9	22,7
Business networks	Clients	1,2	7,6	17,7	73,6
	Equipment suppliers	3,8	12,5	28,5	55,2
	Competitors	4,5	16,7	29,7	49,1
	Consultants	13,2	19,1	27,4	40,3
	R&D labs and firms	20,8	19,1	23,3	36,8
Sector information	Sector conferences and meetings	3,8	18,8	32,1	45,2
	Trade associations	6,6	20,5	38,9	24,0
	Technical and sector literature	1,7	3,8	18,9	75,7
	Fairs and events	4,0	10,4	23,8	61,8
Specialized information	Technical standards and norms	1,9	4,7	15,8	77,6
	Health and hygiene legislation	1,9	9,7	19,3	69,1
	Environment norms and legislation	1,9	9,7	16,3	72,1

Source: Authors’ computation based on direct survey, November-December 2004.

The relatively high scores for Universities seem to suggest that University–industry relations are a concern of a majority of TIFs located in Portugal. The results are therefore supportive of public policy measures targeting (N)TIFs as vehicles of technology transfer and diffusion.

Detailing more the information relative to university-TIF links, Table 3 shows that although in global terms the percentage of TIF that consider Universities an important source of knowledge and information for their innovative activities is high (42,8%), figures vary widely among industries, with relative high-tech industries such as ‘Computing, R&D and firm services’, ‘Electrical’, and ‘Chemicals and plastics’ with values above the average and some of the so-called non-transactionable industries (‘Food, drink and tobacco’, ‘Utilities and construction’, ‘Retail and Wholesale’) presenting the lowest percentages.[12]

Table 3: Importance of Universities as source of innovation-related information and knowledge for Portuguese technology intensive firms, by industry, 2001-2003

Industry	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Agriculture, fishery and extractive industry	0,0	25,0	12,5	62,5	16
Food, drink and tobacco	16,7	20,8	29,2	33,3	24
Textiles	8,1	18,9	40,5	32,4	37
Wood, paper and printing	18,8	18,8	25,0	37,5	16
Chemicals and plastics	16,0	20,0	18,0	46,0	50
Non-metallic minerals	21,1	21,1	15,8	42,1	19
Basic metals and fabric metal products	6,5	22,6	32,3	38,7	31
Machinery	10,8	21,6	29,7	37,8	37
Electrical	6,5	32,3	12,9	48,4	31
Transport and other manuf.	12,5	29,2	25,0	33,3	24
Utilities and construction	16,7	33,3	33,3	16,7	12
Retail and Wholesale	15,6	21,9	28,1	34,4	32
Computing, R&D and firm services	9,9	9,9	18,3	62,0	71
Other services	13,0	26,1	26,1	34,8	23
Column (%)	11,8	21,0	24,3	42,8	
No. TBF	50	89	103	181	423

Source: Authors’ computation based on direct survey, November-December 2004.

[12] Although ‘Agriculture, fishery and extractive industry’ presents the highest percentage of TIFs who consider Universities as a very important source of information and knowledge, we underrate this figure as the number of respondent TIFs is not very representative (see Table 1).

Table 4: Importance of Universities as source of innovation-related information and knowledge for Portuguese technology intensive firms, by size, 2001-2003

Size (no. employees)	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Micro [1,10[	4,3	21,7	28,3	45,7	46
Small [10, 50[	9,7	14,6	23,3	52,4	103
Medium [50, 250[	16,3	20,1	27,2	36,4	184
Large [250, 500[	9,3	24,1	18,5	48,1	54
Very Large [500, …[	8,3	38,9	16,7	36,1	36
Column (%)	11,8	21,0	24,3	42,8	
No. TIFs	50	89	103	181	423

Source: Authors' computation based on direct survey, November-December 2004.
Note: Size classes were constructed upon IAPMEI (1993) methodology.

In terms of size (Table 4) the perception of TIFs concerning the importance of universities presents a kind of U-shaped distribution, with small and micro TIFs on one side, and large and very large TIFs on the other, reporting the highest percentages. These are also the groups of firms that present the lowest figure in the class 'not used'.

Table 5: Importance of Universities as source of innovation-related information and knowledge for Portuguese technology intensive firms, by age, 2001-2003

Age (no. of years in business)	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Startup [1,10]	5,5	18,2	32,7	43,6	55
Non-Startup [11, ...[	12,9	21,6	22,7	42,7	365
Column (%)	11,9	21,2	24,0	42,9	
No. TIFs	50	89	101	180	420

Source: Authors' computation based on direct survey, November-December 2004.
Note: Startup threshold was taken from Almeida et al. (2003).

Almost all (94.5%) start-ups or NTIFs claim to use Universities as a source of information and knowledge to their innovative activities. Moreover, they tend to consider this type of source as important or very important to a slight higher degree than older firms. At first sight, that is, without controlling for other variables likely to influence the TIFs propensity for drawing from Universities, age seems to be negatively related to University drawing.

Table 6: Importance of Universities as source of innovation-related information and knowledge for Portuguese technology intensive firms, by location (NUT II), 2001-2003

Industry	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Norte	9,2	18,4	25,2	47,2	163
Centro	7,5	24,7	20,4	47,3	93
Lisboa e Vale do Tejo	18,0	20,0	25,3	36,7	150
Alentejo	11,1	33,3	33,3	22,2	9
Algarve	0,0	33,3	0,0	66,7	3
Madeira e Açores	0,0	40,0	40,0	20,0	5
Column (%)	11,8	21,0	24,3	42,8	
No. TIFs	50	89	103	181	423

Source: Authors' computation based on direct survey, November-December 2004.

Those TIFs located in the North and Centre regions regard Universities as highly important sources of knowledge for innovation, and are also the regions (excluding the Algarve and the islands) with the lowest figures in the 'not used' category. This suggests that northern and centre TIFs tend to consider Universities an important factor in their innovation dynamics.

Table 7: Importance of Universities as source of innovation-related information and knowledge for Portuguese technology intensive firms, by geographical proximity to universities, 2001-2003

	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Do not contact Universities	25,7	42,8	15,8	15,8	152
Contact **only** the Universities of the **same** district	3,2	12,7	37,3	46,8	126
Contact **several** Universities including those of the same district	5,6	4,7	20,6	69,2	107
Contact **only** Universities of **different** districts	2,8	5,6	27,8	63,9	36
Column (%)	11,9	20,9	24,5	42,8	
No. TIFs	50	88	103	180	421

Source: Authors' computation based on direct survey, November-December 2004.

The vast majority (74.3%) of TIFs that have claimed to have formal contacts with Universities tend to consider this source as highly important.[13] It is interesting to note

[13] The answers obtained to the question put in the questionnaire about whether TIFs have (and the number of) formal contacts with Universities are likely to be overstated in the sense that we did not control or properly define the notion of 'formal contacts'. In future research, this question should be revised indicating types of contacts by degree of formalisation and asking firms to state whether they established these types of contacts and their corresponding frequency.

that the TIFs that contact only the Universities of the same district are those that attribute relatively lower importance to Universities as a source of knowledge for their innovative activities. This suggests that University proximity is important for establishing formal linkages, although neighbouring Universities are not seen as a crucial source of knowledge for the firms when compared with other firms that contacted externally-located Universities.

For TIFs that contact Universities of districts other than the one where they are located, University knowledge is perceived as relatively more critical. Thus, we can surmise from this that Universities are not likely to constitute a decisive factor in TIFs location decisions.

In fact, in our inquiry TIF were asked to indicate on a 1–2–3–4–5 scale the degree of importance for several potential location determinants (1 - no importance … 5 - highly important). These location determinants were, for analysis purposes, grouped together under four different headings (institutional, market - business networks, costs, physical infrastructures and others).

The results for the entire range of location determinants that TIF have considered in their location choices are presented in Table 8. Only around one fourth of TIFs consider Universities highly important in their location decisions, the second lowest determinant following the proximity of competitors. For our sample of respondent TIFs, infrastructures (transport and social) are seen as major location determinants.

Table 8: Location determinants for Portuguese technology intensive firms, 2001-2003 (n=425)

Type	Location determinant	% of firms		
		Low or very low	Medium	High and very high
Institutional	Universities	48,4	26,1	25,4
	Social infrastructures	9,2	37,9	52,8
Business networks	Clients proximity	29,2	22,7	48,1
	Suppliers proximity	34,1	32,0	33,9
	Competitors proximity	56,6	26,3	17,1
Costs	Labour costs	28,4	36,5	35,0
	Energy costs	56,6	20,7	22,8
Physical infrastructures	Transport infrastructures	7,8	20,1	72,1
Other	Fiscal benefits	50,5	17,5	32,0

Source: Authors' computation based on direct survey, November-December 2004.

The proximity to clients also seems to be an important determinant, whereas fiscal benefits, suppliers proximity and labour costs have relatively lower importance than that the literature appears to attribute to them.

It is interesting to note that 'high skill intensive' TIFs are those that reported to a greater extent that Universities are highly important sources for innovation activities.

Table 9: Importance of Universities as sources of innovation-related information and knowledge for TIFs located in Portugal, by skill intensity groups, 2001-2003

	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Low skill intensity TIFs	15,4	28,6	26,9	29,1	175
Medium skill intensity TIFs	9,2	18,4	23,7	48,7	152
High skill intensity TIFs	8,4	11,6	21,1	58,9	95
Column (%)	11,6	21,1	24,4	42,9	
No. TIFs	49	89	103	181	422

Source: Author's computation based on direct survey, November-December 2004.
Note: Low skill intensity TIFs - firms that present a proportion of engineers in total employment between 0% and 5% (not included); Medium skill intensity TIFs - firms that present a proportion of engineers in total employment between 5% and 20% (not included); High skill intensity TIFs - firms that present a proportion of engineers in total employment equal or over 20%.

This seems to suggest that there is a link between human capital endowments and composition and the propensity to draw on Universities. This relation, however, vanishes when we consider education intensity as an indicator for TIFs human capital composition. In fact, Table 10 shows that differences among education groups by the importance attributed to Universities are not substantial.

Table 10: Importance of Universities as sources of innovation-related information and knowledge for TIFs located in Portugal, by education intensity groups, 2001-2003

	% of firms				No. TIFs
	Not used	Low or very low	Medium	High and very high	
Low education intensity TIFs	8,7	21,7	26,1	43,5	69
Medium education intensity TIFs	14,8	18,1	23,5	43,6	149
High education intensity TIFs	10,3	23,2	24,6	41,9	203
Column (%)	11,6	21,1	24,5	42,8	
No. TIFs	49	89	103	180	421

Source: Author's computation based on direct survey, November-December 2004.
Note: Low education intensity TIFs - firms that present a proportion of workers with 12 or more years of formal education in total employment between 0% and 5% (not included); Medium education intensity TIFs - firms that present a proportion of workers with 12 or more years of formal education in total employment between 5% and 20% (not included); High education intensity TIFs - firms that present a proportion of workers with 12 or more years of formal education in total employment equal or over 20%.

Exploratory results seem to convey the idea that having University graduates, in particular engineers, is relevant to the draw on Universities. This supports the arguments and evidence of Schartinger et al. (2001) and Gibbons and Johnston (1974), which point out mobility of human capital as the main knowledge-transferring channel between Universities and firms and the fact that tertiary education constitutes a source of information, which tends to be highly relevant to ‘decode’ new technical information and to incorporate it into the manufacturing process.

The Universities of Porto, Aveiro and Minho are those that present higher percentages of TIFs claiming to have established formal contacts with them in the three-year period of analysis (2001-2003). These are also the Universities with a higher percentage of contacts, with respectively 18.5%, 15.2% and 15% of the total (5965 contacts, which amounts to around 2000 contacts/year). At the other extreme, we have the Universities of the Algarve, Católica (Lisboa and Porto), Beira Interior and Évora.

Table 11: TIFs contacts with Universities, 2001-2003

University	Firms		Contacts		“linkage strength” average of contact intensity (2)/(1)
	Number	%	Number	%	
Algarve	9	1,8	75	1,3	8,3
Católica de Lisboa	14	2,7	123	2,1	8,8
Minho	90	17,5	907	15,2	10,1
Aveiro	65	12,7	894	15,0	13,8
Coimbra	46	9,0	642	10,8	14,0
Nova de Lisboa	34	6,6	340	5,7	10,0
Beira Interior	14	2,7	164	2,7	11,7
Évora	18	3,5	223	3,7	12,4
Porto	92	17,9	1104	18,5	12,0
Católica do Porto	24	4,7	174	2,9	7,3
Lisboa	36	7,0	534	9,0	14,8
Técnica de Lisboa	71	13,8	785	13,2	11,1

Source: Author’s computation based on direct survey, November-December 2004.

It is important to highlight here that the answers of whether TIFs have (and the number of) formal contacts with Universities are likely to be overstated because we did not control for or did not provided firms with a proper definition of ‘formal contacts’. Therefore the comments on Table 11 should be taken with caution.

Taking into account the above limitation, we might point out that the highest intensity of contacts (‘linkage strength’) are associated (in a decreasing order) with the University of Lisbon, University of Coimbra, and University of Aveiro. Católica (Porto and Lisboa) and the Algarve present the lowest ‘linkage strength’.

4. Estimation results and discussion of the main hypotheses

4.1. Model specification

Our endogenous variable is the degree to which firms rely on universities as source of knowledge for innovation, measured by means of a discrete and inherently ordered multinomial-choice variable. Thus, the dependent variable (Y), the degree of importance of universities as source of knowledge and information, takes values from of 0 if TIF responded “no or very low importance”, 1 “low or medium importance”, and 2 if the TIF responded “high and very high importance”.

Given the characteristics of our dependent variable, the most suitable model is an ordered logit (see Greene, 1997). The reduced form of such model is, in our case,

$$\mathbf{y}^* = \boldsymbol{\beta}'\mathbf{x} + \boldsymbol{\varepsilon} \qquad (1)$$

where **y*** is unobserved with

y=0 if $\mathbf{y}^* \leq \mathbf{0}$,

y=1 if $\mathbf{0} < \mathbf{y}^* \leq \mu_1$,

y=2 if $\mu_1 < \mathbf{y}^*$,

with μ’s being unknown parameters to be estimated with $\boldsymbol{\beta}$. Additionally, **x** is a vector of measurable factors and $\boldsymbol{\varepsilon}$ certain unobservable factors. It is assumed that $\boldsymbol{\varepsilon}$ is normally distributed across observations. Normalizing the mean and variance of $\boldsymbol{\varepsilon}$ to zero and one, respectively, with normal distribution, we have the following probabilities (with Λ(.) indicating the logistic cumulative distribution function):

$$\begin{aligned} \Pr ob(y=0) &= 1-\Lambda(\beta' x) \\ \Pr ob(y=1) &= \Lambda(\mu-\beta' x)-\Lambda(\beta' x) \qquad (2) \\ \Pr ob(y=2) &= 1-\Lambda(\mu-\beta' x). \end{aligned}$$

The marginal effects of the regressors, **x**, on the probabilities are not equal to the coefficients. For the three probabilities, the marginal effects of changes in the regressors are:

$$\begin{aligned} \frac{\partial \Pr ob(y=0)}{\partial x} &= -\Lambda(\beta' x)\beta \\ \frac{\partial \Pr ob(y=1)}{\partial x} &= \left(\Lambda(-\beta' x)-\Lambda(\mu-\beta' x)\right)\beta \qquad (3) \\ \frac{\partial \Pr ob(y=2)}{\partial x} &= \Lambda(\mu-\beta' x)\beta. \end{aligned}$$

Note that the marginal effects sum to zero, following from the requirement that the probabilities add to one.

The measurable factors included in the **x** vector are those referred in the above-mentioned hypothesis (Section 2.4), namely: size, age, R&D intensity, 'openness', geographical proximity and human capital intensity.

4.2. Variables proxies and descriptive statistics

As referred above, the dependent variable is proxied by the importance that respondent TIF attributed to universities as source of knowledge and information for their innovative activities.

Concerning the 'structural' independent variables, size is measured by the number of workers (taken in logs) and age is measured by the number of years in business (also in logs). R&D intensity is proxied by the ratio of R&D expenditures to sales.[14]

Regarding to the 'strategic' variable, 'openness', using Laursen and Salter's (2004) methodology was constructed by considering all 15 sources of knowledge or information for innovation listed in Table 2 of this paper (that is, excluding "within the firm" and "university knowledge and information") as a "pool of sources that firms may or may not draw upon as they innovate". In the construction of the variable, each of the 15 sources were coded as a binary variable, "0" being no use and "1" being use of the given knowledge source. Then, 15 sources are simply added up so that each firm gets a 0 if no knowledge sources are used, getting the value of 15 if all knowledge sources are used. Therefore, we assumed here that firms who use higher numbers of sources tend to be more "open" than otherwise.

The human capital intensity variable is proxied using widely used ratios: the number of 'top skilled' workers in total employment, being top skills measured by the number of engineers; and the number of 'top educated' workers in total employment, with top educated represented as the number of workers with twelve or more years of formal education.

Although skills and education are treated in countless studies as synonymous concepts (Harris and Helfat, 1997), more accurately they are distinct though interrelated concepts. Skills can be acquired through education and (formal) training but also (and mainly) through the course of people's activities at work (i.e., learning-by-doing).

[14] It is important to note that all the variables in the inquiry are averages for the three-year period, 2001-2003. Our option for taking the three-year average derived from the need to guarantee that values indicated were not sporadic and abnormal figures.

Rosen (1986) points to the fact that most specific job skills are learned from performing the work activities themselves. Formal schooling complements these investments, both by setting down a body of general knowledge and principles for students, as well as teaching them how to learn.

In order to capture both components of human capital we thought to be interesting to test human capital intensity by using these two alternative (though interrelated) ways of measuring it.

Finally, location related factors are proxied by two different variables: the importance that TIF attributes to the University as location determinant and the 'geographical proximity', that is, whether the universities relative to each the firm has formal contacts are within the firm neighborhood (grossly, in the same district).

The first proxy is measured by a five Likert scale (1=no importance … 5=highly important), based on firms response to the question whether university constitute an important factor in their location decision. The second one is a binary variable, which assumes the value 1 if the TIF has formal contact with universities within its same district and 0 otherwise. We assume that TIF who acknowledge universities as highly important for their location decisions are more likely to draw from them in their innovative activities. Similarly, we would expect that University geographically closer TIF would be more prone to draw from universities.

4.3. Estimation results

Starting by discussing the descriptive statistics (presented in Table 9) of the variables that constitute our econometric model, we may point that our respondent TIF are, on average, of reasonable size (around 80 workers) and with relatively high business experience (about 22 years). In fact, only 13,8% of the TIF are classified as 'start-ups' in the period of study (see Table 5).

Moreover, firms devote, on average, 5% of their sales to R&D efforts, presenting this R&D intensity variable a reasonable variability (the standard variation is twice the mean).

The level of 'openness' of our respondent sample is rather high; on average, TIF indicate that they draw from 13 out of 15 possible external sources of information and knowledge for innovation activities. The majority of TIF (65%) establish formal contacts with universities that are located in the same district (of these, slightly less than half have contacts with both neighbouring and out of the district universities).

Concerning, human capital-related variables, figures indicate that, on average, 16% of TIF total workforce is constituted by engineers and 23% by employees with twelve or more years of schooling. Such percentages show that the respondent TIF are (for the Portuguese standards) relatively highly endowed in terms of human capital.

Without controlling for other variables, linear bivariate correlation estimates evidence that, for the sample in analysis, TIF that possess more open search strategies, are located nearby universities, reckon universities as an important location determinant, and are relatively better endowed with a highly skilled workforce tends to regard universities as an critical source of information and knowledge in their innovative activities.

Additionally, larger firms tend to be those with more experience in business and that present lower R&D intensities and are more poorly endowed in human capital. TIF that present, on average, higher R&D efforts tend to be the most highly endowed in human capital and with formal contacts with neighbouring universities. In the same line, TIF that present higher human capital and R&D interaction terms tend to perceive universities as a crucial location factor. This suggests that, as literature indicates, that universities seems to perform a strategic role concerning the production of high quality human capital and knowledge externalities; these later acting as important levers for attracting firms, making universities "regional machines of knowledge" or "regional boosters" (Malecki, 1985; Florax, 1992).

Table 12: Descriptive statistics

	Mean	SD	Min	Max	Correlations									
					1	2	3	4	5	6	7	8	9	10
Use of University as a source of information and knowledge	1,24	0,747	0	2	-0,07	-0,01	0,11*	0,36**	0,39**	0,47**	0,16**	-0,05	0,18**	-0,01
(1) Firm size (log)	4,29	1,519	0	8,79		0,35**	-0,31**	0,12*	0,05	-0,08	-0,42**	-0,39**	-0,32**	-0,22**
(2) Firm age (log)	3,10	0,820	0	5,19			-0,21**	0,06	-0,04	-0,09	-0,30**	-0,24**	-0,28**	-0,17**
(3) R&D intensity	0,05	0,125	0	1				0,01	0,09	0,12*	0,37**	0,21**	0,46**	0,39**
(4) Openness	13,69	2,015	0	15					0,13*	0,21**	0,00	-0,08	0,05	0,09
(5) Geographical proximity	0,55	0,498	0	1						0,36**	0,14**	-0,02	0,16**	0,08
(6) University as determinant of location	2,55	1,223	1	5							0,16**	-0,01	0,18**	0,12*
(7) Human capital intensity (engineers)	0,15	0,208	0	1								0,19**	0,89**	0,18**
(8) Human capital intensity (education)	0,27	0,258	0	1									0,07	0,65**
(9) Interaction skills and R&D	1,43	2,263	0	11,02										0,29**
(10) Interaction education and R&D	2,23	2,690	0	14,2										

** significant at 1%; * significant at 5%

In order to test our main hypothesis and answer the research questions we estimated an ordered logit model which tries to assess the determinants of the degree of importance that Portuguese TIF attributed to universities as source of knowledge for innovation. Recall that this endogenous variable takes values from of 0 if TIF responded "no or very low importance", 1 "low or medium importance", and 2 if the TIF responded "high and very high importance". Table 13 contains the results of the estimation. In the

Referring to the first hypothesis, which asserted a positive relationship between the use of Universities as a knowledge source and TIFs size, it can be seen from Table 13 that being a small firm increases the probability of using University knowledge and information. Coefficient estimates for the size of the firm come negative and significant at statistical conventional levels in all model specifications. Our findings stand therefore in contradiction with Hypothesis 1 ("Larger TIF are more likely to draw from Universities"). They also stand against the evidence gathered by Laursen and Salter (2004), Cohen et al. (2002) and Mohnen and Hoareau (2003), going more in line with the arguments of Acs et al. (1994), who find that small firms benefit more from University spillovers than larger ones. According to this type of argument, smaller firms would be more likely to draw upon Universities.

In terms of the firm's age, our data, similarly to the work of Laursen and Salter (2004), fail to provide a clear answer. In fact, estimates obtained, regardless of the model, are always insignificant. Thus, our second hypothesis ("Age negatively influences the draw from Universities") cannot be confirmed.

Quite unexpectedly, we find that R&D intensity per se is non significant in explaining the use of University knowledge in innovation activities. As our sample includes only TIFs, which by definition, are intensive R&D performers, a large part of which possess their own R&D labs, there are many firms which perform R&D but do not draw *directly* from Universities in their innovative activities. Notwithstanding, as the literature mentions, these firms tend to draw indirectly from Universities through the employment of trained scientists and engineers.

In fact, when R&D is interacted with the human capital intensity variable, measured in terms of engineers, we have it (Model 5) that for a given ratio of engineers in total employment, TIFs with larger R&D efforts are more likely to draw from Universities in their innovative activities. This seems to suggest, in the line with earlier literature on technology (Nelson and Phelps, 1966) and the argument of Gibbons and Johnston (1974), that human capital endowments and innovative dynamics are intimately connected. As University education and skills (namely in engineering) are crucial for "problem solvers", imparting a more general capability to initiate a search to obtain further relevant information, TIFs with large R&D efforts and a more skilled workforce are more likely to draw from Universities as they are more capable of searching for the right kind of information ("knowledge of knowledge"). Notwithstanding, the absorption variable produces opposite results when we interact R&D with human capital intensity measured by the proportion of workers with 12 or more years of education. It seems in fact that education is important but only at university or tertiary levels, which corroborates Gibbons' and Johnston's (1974) view.

The hypothesis put forward by Laursen and Salter (2004) ("Openness" positively influences the draw from Universities - Hypothesis 4) receives here strong support. Indeed, all models estimated show that TIFs-strategy variable present positive sign and strongly significant coefficients. Thus, we find a strong effect of the degree of openness in the external knowledge search strategy of firms on the probability of using University knowledge in innovation activities. Similarly to the conclusions obtained by the above-mentioned authors, we find that TIFs which are more open in the way they search for new ideas for innovation are more likely to draw from Universities.

Being geographically near Universities, or to put it more rigorously, maintaining formal contacts with Universities within the same districts seems to positively and strongly influence the propensity of TIF to rely on Universities as sources for their innovative activities. Additionally, those TIFs which consider Universities critical factors in their location decisions are also, on average, more prone to draw from Universities. Such results corroborate the argument in a growing number of studies on firm location determinants that refer to the existence of knowledge externalities in regions surrounding research Universities (Acs et al., 1992; Jaffe et al., 1993; Anselin et al., 2000; Woodward et al., 2003). Summing up, our data provides strong support for Hypothesis 5 ("Geographical proximity positively influences drawing from Universities").

The results obtained with respect to Hypothesis 6 ("Human capital intensity positively influences the draw from Universities") are not perfectly clear-cut. Human capital intensity per se when measured in terms of skills (engineers) fails to be statistically significant (Models 1 and 3), whereas when measured in terms of schooling (employees with 12 or more years of formal education) turns out to be significant (at 10%) (Models 2 and 4) but with a negative sign, suggesting that TIFs with a higher proportion of schooled workers are less likely to draw from Universities for their innovative activities. Such results can be justified, at least in part, by the fact that larger TIFs present, on average, larger ratios of highly educated workers, and thus the number of workers with 12 or more years of formal education turns out to be a proxy for size rather than for human capital intensity.

An important and interesting result however is found in Model 5, where the interaction variable of human capital intensity (measured by engineers) and R&D comes with a positive and significant coefficient. Similarly to the R&D intensity hypothesis, once again the indirect effect of human capital on the probability of TIF draw from Universities is here highlighted.

5. Conclusion

The present study attempted to complement existing studies on the theme of firms-University linkages and University location determinants by testing the importance of Universities as sources of information and knowledge use in innovation for TIF, placing special emphasis on somewhat neglected issues such as firms-University geographical proximity and human capital endowments. Moreover, the present work aims to contribute to the firms-University empirical debate relative to the Portuguese economy. Based on this, we endeavour to draw some policy implications on the role of University-TIFs linkages for innovation and regional development.

This research sought to answer the following questions: 1) Are Universities important as sources of information and knowledge use for TIFs innovation activities?; 2) How relevant is University proximity to the TIFs draw from Universities?; 3) Is the TIFs human capital composition a relevant variable in strengthening University-TIFs linkages and thus contributing to enhancing regional innovation capabilities?

Estimations of ordered logit models based on data gathered from a direct inquiry involving 425 TIFs located in Portugal allow us to conclude that:

1. Universities are indeed considered by TIFs located in Portugal as an important source of information and knowledge for innovative activities. Around 88.2% of respondent TIFs claimed to use Universities. However, despite this high percentage, ‘only’ 42.8% of them indicate that the knowledge they draw from Universities is highly important. The most important sources for TIFs are ‘Internal’, ‘Technical standards and norms’, ‘Technical and sector literature’, and ‘Clients’, all encompassing more than seventy per cent of the respondent TIF in the ‘highly important’ class.
2. Although few TIFs claimed that Universities were an important factor of location. Evidence based on the logit models indicates that proximity is in fact highly relevant. Being geographically near Universities seems to positively and strongly influence the propensity of TIFs to rely on Universities as sources for their innovative activities.

Therefore, we can conclude that the point made in location-related literature concerning the existence of knowledge externalities in regions surrounding research Universities is indeed applicable in the Portuguese context.

3. The TIFs' human capital composition (measured by the engineers proportion) although not particularly critical per se, when interacted with R&D efforts strongly and positively influences the probability of the TIF draw from Universities. In this vein, and in line with earlier literature on technology (Nelson and Phelps, 1966), and information sources (Gibbons and Johnston, 1974), University education and skills (namely in engineering) appear as a crucial element for "problem solvers", imparting a more general capability to initiate a search to obtain further relevant information. TIFs with large R&D efforts and a more skilled workforce tend therefore to be more prone in relying on Universities, as they are more capable of searching for the right kind of information ("knowledge of knowledge").

The work undertook presents several limitations, which may nevertheless motivate interesting avenues for further research. One limitation concerns the concept of TIFs. We adopt a widely-used definition ('firms that perform R&D activities') conveyed, among others, by OCED studies supported by the Frascati Manual (OECD, 2002). A more rigorous definition would imply researching and proving whether firms that claim to perform R&D activities were in reality 'innovative' in the sense that they generate some type (product, process or market) of innovation.

Another limitation, which we highlight in the main text, is the vague definition of 'formal contacts'. We did not control for or provide firms with a proper definition of 'formal contacts' with Universities. Thus the TIFs' answers to the question about if and the number of formal contacts they established in the three year period of analysis (2001-2003) with Universities are likely to be overstated. Further research can overcome this limitation by providing firms with a list of items conceptually included in the notion of 'formal contacts' (e.g, 'R&D cooperative projects').

Still, related with University contacts and linkages, another stimulating path of research concerns analysing why some Universities generate large and more long-term links with firms than others. Finally, extending this line of research to non-TIFs would provide a more comprehensive picture of our business reality.

Table 13: Ordered logit regression, explaining the use of knowledge created in universities for TIF technological innovation activities, 2001–2003

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Coef.	*p-value*	Coef.	*p-value*	Coef.	*p-value*	Coef.	*p-value*	Coef.	*p-value*	Coef.	*p-value*
Size (log)	-0,198	0,01	-0,278	0,00	-0,157	0,07	-0,220	0,01	-0,210	0,01	-0,268	0,00
Age (log)	0,110	0,40	0,0415	0,75	0,161	0,28	0,109	0,46	0,106	0,42	0,030	0,82
R&D intensity	0,282	0,76	0,747	0,45	0,200	0,83	0,609	0,51				
Openness	0,415	0,00	0,426	0,00	0,404	0,00	0,414	0,00	0,414	0,00	0,434	0,00
Geographical proximity	1,438	0,00	1,450	0,00					1,436	0,00	1,498	0,00
University as an important location determinant					0,860	0,00	0,863	0,00				
HC intensity (engineers)	0,853	0,15			0,560	0,38						
HC intensity (top educated)			-0,901	0,05			-0,849	0,08				
HC intensity (eng)*lnR&D									0,082	0,12		
HC intensity (educ)*lnR&D											-0,070	0,10
Constant	-4,264	0,00	-3,524	0,00	-5,667	0,00	-5,085	0,00	-4,162	0,00	-3,702	0,00
μ_1	2,35	0,00	2,367	0,00	2,520	0,00	2,535	0,00	2,351	0,00	2,363	0,00
N	369		369		369		369		369		369	
Log likelihood	-328,02		-326,87		-311,16		-309,81		-327,96		-327,53	
Restricted log likelihood	-382,32		-382,32		-382,32		-382,32		-382,32		-382,33	
Likelihood ratio test	108,61	0,00	110,90		142,33	0,00	145,02	0,00	108,73	0,00	109,59	0,00
Pseudo R^2	22,7		23,1		27,8		28,2		22,8		22,9	
McFadden R^2	14,2		14,5		18,6		19,0		14,2		14,3	

Note: Controlling for industry effects, results come slightly changed with size variable becoming statistically insignificant. Moreover, industry dummies (excluding agriculture and extractive industry) estimates fail to be statistically significant. Given that the number of observations is not as large as it would be necessary to perform such controls, we opt to not present the models controlling for industry effects.

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