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SPECIAL ISSUE PAPER

Proximity to knowledge sources and the location of knowledge-based start-ups

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Abstract We use detailed longitudinal data on firms, human capital and universities to study the impact of geographical proximity to knowledge sources and local absorptive capacity on the regional location of knowledge-based start-ups. Using municipalities as the regional unit of analysis, we examine the influence of the regional distribution of universities, yearly numbers of students and graduates, and workforce education on new start-up numbers. We estimate models of regional entry using zero inflated negative binomial regression. We find that local access to knowledge and human capital significantly influences entry by knowledge-based firms into regions, after controlling for other regional-level variables.

JEL Classification J24 · M13 · R12

1 Introduction

A widespread and diverse literature regards concentration as "the most striking feature of the geography of economic activity" (Krugman 1991, p. 5). The performance

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of regional economies varies markedly in terms of wage, wage growth, employment growth and innovative performance (Audretsch 1998; Porter 2003). Different streams of literature have looked at spatial differences in the distribution of production and innovation, generally concluding that these are due to increasing returns (or agglomeration externalities) associated with a variety of sources (Baptista 1998; Audretsch 2003; Audretsch and Feldman 2004). Most empirical studies have suggested that firms are more productive and innovative when clustered within a location (Faberman 2005). Some of these studies have looked at firm growth. For instance, Glaeser et al. (1992) explored how positive externalities arising from both regional industry concentration and diversity may contribute to firm employment growth. Other studies have linked agglomeration externalities with higher firm innovative performance (Baptista and Swann 1998; Feldman and Audretsch 1999).

The literature on the location of innovation has emphasised the role played by agglomeration externalities associated with access to knowledge spillovers. Spillovers occur whenever a firm shares knowledge with other bodies performing research and development,[1] such as other firms, universities and government institutions (Griliches 1992). If information about new technologies, goods and processes, flows locally more easily than over great distances, than establishing direct contact with entities that can produce knowledge which is valuable for a firm's activity should be one of the main driving forces leading to the geographic concentration of both production and innovative activities.

Regional economic development is a complex process resulting from the interaction of numerous factors, including entrepreneurial activity (Moyano et al. 2005). Entrepreneurship can be seen as a process of exploiting opportunities that exist in the environment, converting ideas (which may arise from R&D activities) into successful businesses and creating value through innovation (Shane 2000). Thus, while the creation of new firms likely plays a central role in spawning regional economic advances (Storey 1984; Fritsch and Mueller 2004), the pervasiveness of entrepreneurial activities across regions should vary according to the pools of innovative opportunities and human capital available in each region (Shane 1996).

The present paper explores the differences in new firm formation in knowledge-based sectors across Portuguese regions, looking at their relationship with accessibility to knowledge sources, and the availability of human capital capable of exploiting such knowledge to generate commercial innovations. This analysis aims at extending our knowledge of the mechanisms influencing the location of knowledge-based firms, which have been found to have a greater potential to generate employment growth in the medium and long term (Baptista and Preto 2006), thus aiding policy-makers in influencing the structural determinants that impact start-up rates and employment growth at the regional level.

The paper is organized as follows. The following section presents some literature background on new firm location, developing hypotheses to be tested with regard to the role played by accessibility to knowledge sources in the location choice of start-ups. Section 3 presents the data and methodological approach used in the present study,

[1] Without having to pay for such knowledge in a market transaction.

while Sect. 4 reports the results obtained. Section 5 presents our main conclusions, and highlights avenues for improving and broadening this research.

2 Knowledge accessibility and the location of start-ups

2.1 Knowledge spillovers and firm location

Most works on industrial location consider the existence of agglomeration externalities as a key determinant of the geographical concentration of economic activities. Externalities contribute to firm competitiveness and innovative performance through mechanisms that involve both concentration and diversity of industries (Glaeser et al. 1992), as well as the local presence of specialised workers, intellectual capital, customers and suppliers, and other sources of information concerning market conditions and technological developments (Baptista 1998; Audretsch 2003). Although using different theoretical tools, both urban economists and economic geographers have long advocated that urban agglomerations grow, amongst other things, because they allow people to interact and learn from each other (Jacobs 1969; Henderson 1974; Scott 1992; Florida 1995; Gertler 1995; Fujita and Thisse 1996; Simmie and Lever 2002). The frequency of such interaction is enhanced by geographical proximity.

It is therefore a general belief that location matters to the development and growth of industries (Stahlecker and Koschatzky 2004). Much literature has been developed around the notion that firms tend to concentrate in certain regions so they can benefit from co-location. A particular stream of this literature focuses on advantages arising from sharing and accessing information and knowledge. Works in this stream argue that the regional environment is more likely to impact new, small firms than their large counterparts (Keeble and Wilkinson 1999; Simmie 2002). One reason for this is the fact that such firms often lack the complementary assets to develop and commercialize new products, and hence locate in geographical areas where such assets are available and can be contracted or licensed. As industries become concentrated in a few regions, new firms should be attracted to those same regions by the existence of such complementary assets, thus reinforcing this spatial clustering process (Boschma and Lambooy 1999).

If knowledge spillovers represent a significant form of agglomeration externalities, then the location decision of new firms should be influenced significantly by access to the sources of such spillovers, including specialised human capital and institutions performing R&D activities (Audretsch et al. 2005). Also, the propensity to cluster geographically should be higher in industries where new knowledge plays a more important role as such knowledge is less likely to be codified and easy to transmit over great distances, with no need for personal contact (Audretsch and Stephan 1996; Baptista and Swann 1999). Thus, access to knowledge sources should be particularly significant for high technology and knowledge-based industries and services.

Companies in innovative sectors tend to choose locations where significant knowledge-generating activities associated with these sectors occur (Zucker et al. 1998, 2002; Audretsch and Stephan 1996). These activities may be performed by universities or other firms and imply the presence of world class scientific research and human capital. Recent literature has advocated that knowledge spillovers play an important role in fostering entrepreneurship and innovative activity (Sorenson and Audia 2000; Baum and Sorenson 2003). Spillovers from universities, as well as from private firms, have been recognized as key sources promoting firm innovation and performance (Stuart and Sorenson 2003; Hall et al. 2003). Stahlecker and Koschatzky (2004) indicate that spatial proximity matters for the founding and early performance of firms in the knowledge intensive business services sectors. Also, Capello (2002) has found that high tech sectors display high spatial concentration.

Empirical studies have found that new firm location at the regional level is significantly influenced by differences in industry intensity, population growth, and income growth across different locations (Armington and Acs 2002). In studying regional variations in new firm formation, Reynolds et al. (1994) and Audretsch and Fritsch (1994) identified a number of geographic-specific characteristics that impact the location of new firms. These characteristics were generally based on factors identified in earlier studies by Carlton (1983) and Bartik (1985): firm birth rates were highest in regions with high proportions of employment in small firms, demand growth, employment specialization, and population density. In the Portuguese context, Cesário and Vaz (2004) found that certain regions generate a better entrepreneurial environment and have a better potential for the development of new businesses, while Costa and Teixeira (2005) found evidence that proximity to universities influences positively the innovative activities of technology-based firms.

Relatively few studies have focused on the influence of access to knowledge sources on the locational choice decision of new firms. Audretsch et al. (2005) found that new knowledge and technology-based firms have a high propensity to locate close to universities, presumably in order to access knowledge spillovers. Karlsson and Nyström (2006) find that accessibility to company R&D has a stronger impact on new firm formation than accessibility to university R&D. However, most of the literature on the location of new firms does not set high tech industries apart from the remaining sectors. Considering the specific knowledge and human capital requirements of firms in high tech industries, it can be argued that such a distinction should be made (Bade and Nerlinger 2000). According to Markusen et al. (1986), the innovative nature of high tech industries demands specific conditions to develop. Hence, knowledge sources should be a especially significant determinant of start-up location choices for knowledge-based industries and services.

2.2 Absorptive capacity and geographical proximity

As new knowledge spills over, one person may discover an opportunity and another may exploit it. Such knowledge may be more than just about products and processes, including also organizational forms, management procedures, or other industry trends (Anselin et al. 2000; Gilbert and Kusar 2006). Therefore, knowledge spillovers represent key sources of opportunities for both new and existing firms to enhance process efficiency, make product improvements, and develop technological and organizational innovations (Acs and Plummer 2005).

While the generation of new knowledge requires qualified human capital, so does the ability to absorb such knowledge. As established by the well-known work of Cohen and Levinthal (1989, 1994), firms differ in their ability to absorb the pool new knowledge resulting from research which becomes accessible, independently of the degree or nature of its development. Such differences result from differences in the firms' own abilities to perform R&D and, therefore, in the quality of their human capital. This suggests that the amount of positive knowledge-related externalities generated in a region depend not just on the local supply of knowledge and information spillovers, but also on the existence of a local labour pool which is capable of absorbing such spillovers generating commercial innovations (Shane 1996; Iammarino and McCann 2006). Andersson et al. (2005) found that patents are responsive to the spatial distribution of workers at different levels of education, as well as to the distribution of private and university R&D facilities.

2.3 Universities as knowledge sources

The local presence of universities can generate positive externalities through both the performance of knowledge-generating R&D activities and the education of specialised human capital, capable of absorbing such knowledge. Acs et al. (1994) find that small firms are recipients of R&D spillovers generated both in universities and in the R&D centres of their larger counterparts, and such spillovers are apparently more significant in stimulating innovative activity by small firms than by large corporations. Anselin et al. (1997) find evidence of local spatial externalities between university research and high technology innovative activity. Feldman (2000) reports strong evidence in favour of a growth effect of geographical clusters influenced by active research universities for the United States. Bade and Nerlinger (2000) find a strong positive correlation between the number of new technology-based firms and the location of R&D facilities for West Germany. Fisher and Varga (2003) provide evidence of the importance of geographically mediated knowledge spillovers from university research activities to regional knowledge production in high tech industries in Austria. They find that such effects differ across industries, and increase with geographical proximity. Acosta and Coronado (2004) find that companies in those regions with a more favourable scientific environment make greater use of scientific knowledge, as indicated by the use of scientific citations in patent documents. Other studies, such as Bania et al. (1993), find that the relationship between university research and firm births varies across industrial sectors. Based on these arguments, we formulate the following hypothesis:

> H1: The number of higher education institutions in a region has a positive effect in determining entry of knowledge-based firms in that region.

Geographical proximity of an academic institution to a knowledge intensive industry may be a source of positive knowledge externalities, since firms can cultivate relationships with universities, participating in research consortia and partnering with academics that do related scientific work (Audretsch and Feldman 2004). Universities can be viewed as an important source of knowledge not only through the development of research activities, but also as the primary generator of qualified human capital that is capable of comprehending such knowledge. In addition to educating human capital which may be directly involved in the creation of new firms, either as founders or key employees, university scientists may also act as facilitators in the contact between local firms and their own (national or international) networks of colleagues, thus widening their knowledge sources. For instance, personal networks of academics and industrial researchers, may lead to the commercial exploitation of knowledge generated at universities by existing firms or university spin-off start-ups. Evidence supports that highly educated resources available from universities will contribute positively to knowledge transfer (Audretsch et al. 2005). In addition, fresh graduates can be important channels for disseminating the latest knowledge from academia to the local high tech industry (Varga 2000). Therefore, we expect that knowledge embedded in new graduates is likely to be transferred to firms in neighbouring locations:

H2: Regions with higher number of university graduates are more likely to have higher number of new firms in knowledge-based sectors.

In addition to graduates, students can also serve as means for the transmission of knowledge from the university to the firms. Universities producing more students may be able to can attract more firms to locate within close geographic proximity. Previous research has shown that student may be an important mechanism transmitting knowledge (Audretsch et al. 2004). Based on this research we test the hypothesis:

H3: Regions with higher number of university students are more likely to have higher number of new firms in knowledge-based sectors.

There is no theoretical reason to expect the knowledge spillovers mechanism to be different across academic disciplines or that availability of knowledge in different disciplines has distinguished impacts on location decisions of firms (Audretsch et al. 2004). On one hand, one can argue that the more generic nature of social sciences makes geographic location matter less to absorb knowledge from academic research. In contrast, location is more important in the natural sciences, reflecting the specialized nature of scientific knowledge (Audretsch et al. 2004). On the other hand, it is possible to argue that research in natural sciences relies more in codified knowledge while social sciences are more tacit in nature. Consequently we would expect a greater influence of research in the fields of social sciences on location of in the same area where this research is accomplished (Cassia and Colombelli 2008).

According to the results obtained by Audretsch et al. (2004), firms tend to locate in geographic proximity to universities with a high number of students, in both the natural sciences and social sciences. Cassia and Colombelli (2008) observe, through the number of articles published in the social science, that research activity in this field will have a positive impact on the growth of firms in the region. On the opposite side, they observe that research intensity in natural science is less important for the firms in their sample.

The presence and number of graduates in different fields indicates the human capital and knowledge available in each field. We expect that regions with more knowledge in natural sciences and engineering will be more likely to have higher spillovers to high-tech new ventures and those universities with a high student enrolment in the natural sciences and engineering will attract firms in knowledge intensive industries to locate within a closer geographic proximity. In addition, knowledge in social sciences may be more important for knowledge intensive business services; firms in knowledge-intensive service sectors, such as business services, may be particularly dependent on knowledge in social sciences and thus are motivated to interact with universities conducting research in this field (Cassia and Colombelli 2008). Therefore, we expect that universities with a higher student enrolment in social sciences will attract firms in knowledge business services to locate within a closer geographic proximity. Based on these premises, we test our hypothesis four:

> H4: Specific types of human capital have a different effect on entry of firms in knowledge intensive industry and services in regions.

3 Data and methodology

3.1 Data and variables

The data concerning new firm formation used for empirical estimation in the present paper come from the *Quadros de Pessoal* database, which results from information gathered yearly by the Portuguese Ministry of Social Security and Labour on the basis of mandatory information submitted by firms. This is a longitudinal matched employer-employee database which includes extensive information on all private firms, establishments, workers and business owners in the Portuguese economy for the period 1982–2003.[2] We confine our analysis to knowledge intensive business services (KIS) and knowledge-based manufacturing (high and medium-high tech firms), building a dataset containing all new knowledge-based start-ups in these sectors entering in the period 1992–2003. Start-ups of new firms were identified as an entry in the yearly database,[3] checking all information back to 1982, and cross-checking this date with the earliest employee admission date. Firms entering before 1992, and firms for which the entry date could not be identified, were not considered in our analysis. New firms were assigned to the 275 Continental Portuguese municipalities (*Concelho*).[4] Additional data on municipalities was gathered from the National Institute of Statistics (INE). Information on universities, numbers of students, and graduates was collected from the Ministry of Science and Higher Education (MCTES). We followed the OECD classification of knowledge-based industries, aggregated by technology level, which is defined as the sum of high technology and medium-high technology industries, post and communications, finance and insurance and business services (OECD 2002).

Following Audretsch and Fritsch (1994), and Figueiredo et al. (2002), the present study does not focus on capturing factors which may affect entry rates on a national or global level but are unlikely to vary across regions in the same country, such as the

[2] See Cabral and Mata (2003) for a description of the quality and coverage of the data.

[3] Only new firm start-ups are considered, so new plants/establishments by existing firms are excluded from the analysis.

[4] Concelho is a small administrative area in Portugal. The 275 Portuguese concelhos (mainland) have an average area of 322.5 km^2.

Table 1 Summary statistics

Variables	Mean	SD	Min	Max
Entry in services	8.018	31.532	0	761
Entry in industries	0.794	2.016	0	25
No. students	1,198.480	8,205.681	0	128,538
No. graduates	148.738	1,103.152	0	21,081
No. universities	0.874	5.075	0	84
No. students in social sciences	480.284	4,201.460	0	69,805
No. students in engineering and basic sciences	550.132	3,398.434	0	59,100
No. graduates in social sciences	106.236	851.421	0	16,631
No. graduates in engineering and basic sciences	38.552	262.825	0	4,450
Work force education (years)	6.132	0.843	1.813	9.609
Population density	274.487	798.511	6.240	7,839.5
Sales volume per capita (ln)	7.845	2.628	−1.302	12.185
KBE firms per thousand inhabitants	0.989	0.862	−0.323	9.616
Distance to administrative centre	32.231	18.706	0	88
Distance to Oporto	174.104	116.574	3.5	463.5
Distance to Lisbon	198.106	116.574	6.5	396

minimum efficient scale in different sectors, the cost of capital, or macroeconomic fluctuations (see, for instance: Siegfried and Evans 1994). We are mainly concerned with factors that may affect differences in firm entry across regions.

The variables used in the empirical estimation are presented in Table 1, together with their descriptive statistics. The dependent variable used in the study is the number of new start-ups in each year and in each region. Following Fritsch and Falk (2007), we use the number of new firms instead of the start-up rate as dependent variable, as start-up rates may vary with changes in employment and numbers of firms in the respective industry and region. Numbers of start-ups vary considerably across municipalities, including several occurrences of zero births, and also very high numbers of start-ups for the Lisbon municipality. Also, high and medium tech industry start-ups are considerably less than knowledge intensive service (KIS) start-ups.

As explanatory variables, we use three different measures of knowledge accessibility: the number of higher education institutions; the number of students enrolled in higher education institutions; and the number of graduates. In addition, we differentiate between specific kinds of university students and graduates. We built two groups of students and graduates (1) basic sciences and engineering and (2) business, economics and social sciences. The number of institutions in a region measures knowledge production in the region (Bania et al. 1993; Audretsch et al. 2005). The number of students indicates knowledge assimilation.[5] These variables provide a measure of the knowledge produced by universities in the regions, which can be appropriable by firms,

[5] This measure has the advantage of capturing the relative size of higher education institutions: one large university may have a more significant impact than two smaller ones.

therefore representing an important source for entrepreneurial opportunities. The number of graduates indicates the creation of human capital by a region in each year. If start-ups are created as the result of the exploitation of knowledge embodied in people, regions with higher concentrations of university graduates will also show higher levels of firm formation in knowledge-based sectors (Giarratana 2004). In addition, there is evidence showing that entrepreneurs start their firms in regions where they have lived and developed their social networks so it seems reasonable to assume that scientists and recent graduates will start firms in the locations where they undertook their studies, or in adjacent regions (Figueiredo et al. 2002; Michelacci and Silva 2005).

Several control variables are also used to account for other factors affecting the number of start-ups. New firm creation is likely to be associated with the size of the regional market. Hence, we use total sales per capita as a measure of regional development. Agglomeration externalities associated with knowledge spillovers do not originate solely in universities. Other firms may also be a significant source of knowledge. The density incumbents in a region has been shown to affect local firm formation rates significantly (Baptista and Swann 1999; Kangasharju 2000; Acs and Plummer 2005). We use the number of firms in knowledge-based sectors in the region (per thousand inhabitants) as a measure of such agglomeration effects. If spillovers of knowledge generated by incumbents and picked up by potential entrants are significant, we expect this variable to affect entry of new firms in the region positively. Moreover, large numbers of incumbents are likely to signal low barriers to entry, thus reinforcing this effect.

As a measure of the human capital in the regions, we use the logarithm of average years of education of the labour force in the region. Previous research has shown a positive relationship between measures of human capital and entrepreneurial activity at a regional level (Audretsch and Feldman 2004; Andersson et al. 2005). Accordingly, we expect that higher levels of human capital will have a positive effect on new firm entry in knowledge-based sectors.

The logarithm of total population per square metre was used as a measure of regional demand size, which should represent an attraction for start-ups. Kangasharju (2000) indicates that many new firms are established to supply clients in local markets. Thus, we expect to find higher firm formation in regions with higher population density. In addition, we use two measures of urban accessibility: firstly, distances in kilometres (km) to the metropolitan centres of Lisbon and Oporto (the two major urban areas in Portugal) gauge access to the country's largest markets; secondly, access to regional markets is captured by the distance in km from each municipality to the corresponding district's administrative centre. These variables also proxy access information about market and regulatory requirements, as information is usually more readily available in core regions (Figueiredo et al. 2002). We expect more firms to locate closer to urban centres.

3.2 Methodology

Our analysis introduces knowledge accessibility as a determinant of the number of new entrants in knowledge-based sectors, while controlling for a set of variables believed to affect differences in entry levels across regions. We performed separate regressions for services and manufacturing, to avoid correlation issues (see Table 2). In addition, we introduced time dummies to account for time-specific influences, such as differences in the effects of business cycles across regions. Since our dependent variable is the number of new firms entering in each region, count data regression is used. We use pooled panel data observations for the 275 municipalities.

Given the high variability in the number of entrants across municipalities, and the large number of zero entrants observed, the Poisson distribution is not used in the present study. In cases where there is overdispersion, i.e. where the sample variance is higher than the sample mean, the Poisson variance assumption does not hold (Cameron and Trivedi 1986, 1990). A Pearson residuals test was performed, confirming the inadequacy of the Poisson distribution to our sample. Since our dependent variable contains many zero values (more than 25% for services and more than 50% for industry), we use the zero inflated negative binomial model for the estimations presented (see, for instance: Greene 1994; Mullahy 1997). Upon estimation, the Vuong test confirmed the appropriateness of the zero inflated models for our sample.

Results obtained by Figueiredo et al. (2002) show that founders of new firms in Portugal tend to locate their businesses in close proximity to their homes, and therefore a significant number of entrepreneurs set up their businesses in their own municipality. However, we still control for possible spatial autocorrelation, by applying a spatial cross-regressive model to account for the effects of the adjacent region, following the procedure made by Fritsch and Falk (2007), we include dummy variables for the different districts (distritos[6]) and additional dummies for the nuts 2 regions. In these estimations, we cluster the data in the regions and thus control for intraregional correlation.

4 Results

4.1 Geographic distribution of knowledge-based firms

Figure 1 displays the distribution of knowledge-based firms (high and medium tech industry and KISs) per thousand inhabitants in each of the 275 Portuguese municipalities for the years 1992 and 2002. Portuguese municipalities are grouped into 18 administrative districts. The maps show a considerable increase in the number of knowledge-based firms from 1992 to 2002, consistent with the general emergence of knowledge related activities in developed economies. The maps reveal a high concentration of firms along the coastline, with greater incidence in the north of the country.

In 1992, knowledge-based activities were mainly concentrated in a few key regions, namely Lisbon, Oporto, Aveiro, Faro, and surrounding areas, corresponding to the largest urban agglomerations. In addition, the municipalities of Leiria and Marinha Grande displayed a high concentration of firms, associated with the strong cluster of glass and moulding industries which had developed over the years in those areas.

[6] The distrito is a higher administrative region level, which is composed by several adjacent concelhos. The Portuguese mainland is divided in eighteen distritos with an average area of 4,926.7 km^2.

Table 2 Correlation matrix

	Entry services	Entry industry	Students	Graduates	Universities	Work force education	Pop. density	Sales volume per capita	KBE firms	Dist. admin. centre	Distance Oporto	Distance Lisbon
Entry services	1											
Entry industry	0.6166	1										
Students	0.3591	0.2244	1									
Graduates	0.4823	0.3502	0.8229	1								
Universities	0.5469	0.3987	0.6598	0.7411	1							
Work force education	0.4544	0.2657	0.1702	0.2255	0.2897	1						
Pop. density	0.5746	0.3677	0.2649	0.3193	0.3491	0.2857	1					
Sales volume per capita	0.4441	0.3738	0.1221	0.1849	0.2488	0.5219	0.2882	1				
KBE firms	0.5067	0.4745	0.1521	0.2254	0.3076	0.6354	0.2572	0.6734	1			
Distance to administrative centre	−0.3103	−0.3885	−0.081	−0.1815	−0.1377	−0.1159	−0.3375	−0.2455	−0.1811	1		
Distance to Oporto	0.0245	−0.1169	−0.0092	−0.0624	−0.027	0.1083	−0.0301	0.0397	0.1249	0.2191	1	
Distance to Lisbon	−0.1438	−0.0644	−0.0176	0.0113	−0.0491	−0.1476	−0.1303	−0.2954	−0.2168	0.0664	−0.4347	1

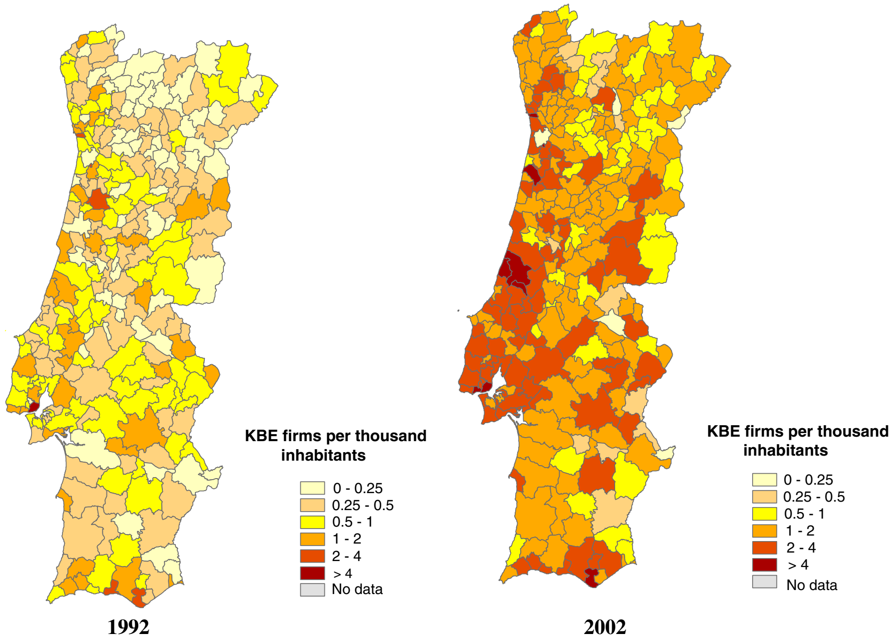

Fig. 1 Distribution of knowledge-based firms in Portuguese municipalities in 1992 and 2002

By 2002, the geographical distribution of knowledge-based firms across the country had become more even, although the difference between coastline and inland areas is still significant. The regions of Lisbon, Oporto, Aveiro and Faro maintain their prominence in terms of knowledge-based firms, but Braga, to the north of Oporto, and Coimbra, in-between Lisbon and Aveiro, have also emerged as major economic centres. The map also shows an increasing sprawl of firms from the core municipalities towards the surrounding areas, likely due to rising congestion costs (i.e. real estate prices and transport/commuting times). While new firms seem to be increasingly locating in municipalities adjacent to core areas, inland regions still display relatively low densities of knowledge-based economic activities. This is particularly striking given that these regions benefited the most (in per capita terms) from EU cohesion funding, being the target of considerable investments in both physical and knowledge infra-structure (i.e. new universities and research units).

4.2 Estimation results

For the manufacturing firms (high tech and medium-high tech), absorptive capacity seems to matter more than actual knowledge creation by universities: while the number of students and graduates in each year significantly increase the probability of one more firm entering the market, the local presence of a university has no significant impact. Table 3 shows that one more graduate increases the probability of entry by 0.5% (column I), while one more student increases the probability of a

Table 3 Regression results for high and medium-high tech manufacturing

	High and medium high tech					
	I	II	III	IV	V	VI
Graduates	0.005* (0.003)			0.004 (0.004)		
Students		0.004* (0.002)			0.004*** (0.001)	
Universities			0.004 (0.003)			0.004 (0.004)
Work force education	−0.323 (0.427)	−0.37 (0.411)	−0.305 (0.413)	−0.684 (1.578)	−0.73 (1.240)	−0.653 (1.338)
Sales volume per capita	0.062 (0.066)	0.058 (0.065)	0.06 (0.063)	0.05 (0.345)	0.043 (0.341)	0.047 (0.322)
KBE firms	0.298*** (0.024)	0.301*** (0.024)	0.300*** (0.025)	0.310*** (0.114)	0.310*** (0.114)	0.311** (0.127)
Pop. Density	0.139** (0.066)	0.142** (0.063)	0.141** (0.065)	−0.007 (0.214)	−0.006 (0.195)	−0.005 (0.208)
Distance to administrative centre	−0.245*** (0.073)	−0.252*** (0.073)	−0.248*** (0.074)	−0.04 (0.123)	−0.049 (0.117)	−0.042 (0.125)
Distance to Oporto	−0.129* (0.077)	−0.125 (0.076)	−0.131* (0.077)	−0.557** (0.258)	−0.553** (0.232)	−0.562** (0.252)
Distance to Lisbon	−0.095 (0.060)	−0.093* (0.057)	−0.096 (0.059)	−0.007 (0.553)	−0.001 (0.516)	−0.007 (0.531)
Dummy for years	Yes	Yes	Yes	Yes	Yes	Yes
χ^2	16.46*	14.87	16.12*	601.08***	47.35***	44.80***
Dummy for Distritos	No	No	No	Yes	Yes	Yes
χ^2				753.70***	638.95***	3,385.87***
Dummy for nuts2	No	No	No	Yes	Yes	Yes
χ^2				5,034.11***	6,077.08***	6,224.94***
Constant	1.276 (2.043)	1.365 (1.915)	1.268 (1.956)	4.079 (12.432)	4.194 (11.169)	4.047 (11.554)
Observations	2,738 (2,006 zero observations)	2,738 (2,006 zero observations)	2,738 (2,006 zero observations)	2,738 (2,006 zero observations)	2,738 (2,006 zero observations)	2,738 (2,006 zero observations)
χ^2	1,127.51***	1,108.43***	1,096.51***	4,840.60***	542.64***	625.94***

Table 3 continued

	High and medium high tech					
	I	II	III	IV	V	VI
McFadden R^2	0.554	0.554	0.554	0.568	0.568	0.568
ML R^2	0.675	0.675	0.675	0.684	0.684	0.684
Cragg and Uhler R^2	0.777	0.777	0.777	0.788	0.788	0.788

I, II and III—zero inflated negative binomial model. IV, V and VI—zero inflated negative binomial model with standard errors adjusted for clustering. Robust standard errors in parentheses

* Significant at 10%; ** significant at 5%; *** significant at 1%

new firm entering by 0.4% (column II). In the estimations clustered for the region only the number of students in each year significantly increases the probability of one more firm entering the market; the coefficient obtained shows that one more student increases the probability of entry by 0.4%, (column V). The number of graduates and universities provided insignificant results (columns IV and VI). These results lead us to reject hypothesis 1 for high and medium-high tech sectors, give partial support to hypothesis 2 and confirm hypothesis 3. These results show that universities contribute to high tech mainly through the production of levels of human capital, and not so much through the creation of new knowledge. Nevertheless, our results suggest that the effect of the presence of universities in regions in high tech entrepreneurial activities is important.

The regional average work force education displays a non-significant coefficient in all the estimations. This may suggest that more educated workers are more attracted by paid employment in large incumbents, and are unwilling or unable to recognise and take advantage of opportunities for new business creation. It may also be that pools of highly skilled labour in most municipalities are still insufficient to fulfil demand by incumbents, thus leading to high wages and greater opportunity costs of starting a firm for these highly skilled workers. Other control variables display the expected results. The numbers of firms and the population density have positive effect, suggesting that local market size has a positive impact on new firm creation. The results obtained for the urban accessibility reveal that increases in distance to administrative centres and to the largest metropolitan areas lead to decreases in new firm entry. This suggests that high and medium-high tech firms aim at markets that go beyond their local surroundings, and transport costs matter for location, particularly if scale economies in production are significant (thus confirming the arguments put forward by Krugman (1991). These results loose their significance once we add the regional dummies and cluster for the region, as expected, since we are controlling for intra-group correlation.

The results in Table 4 show that engineering and basic science students and graduates have a positive effect on new firm entry in high and medium high-tech sectors, suggesting that the presence of universities teaching technology degrees has an impact in the development of regional activities in knowledge intensive industry and that engineering graduates may undertake in high-tech entrepreneurial activities in the regions where they study. On the other hand, social science graduates and students have no impact on new firm entry. These results suggest that the effect of human capital resides not only in the presence of universities in the region, but also on the graduates leaving university each year. Thus, it seems as if the knowledge-being generated in local universities is being absorbed by aspiring entrepreneurs. This is consistent with Audretsch et al. (2004) who found evidence that research-intense universities in the natural sciences are more attractive for start-ups. However, these results do not hold in the spatial cross-regressive estimations (columns III and IV). Therefore, the results in Table 4 only allow us to partially confirm hypothesis 4 for high and medium high-tech sectors.

Table 5 shows that the impact of access to knowledge sources and absorptive capacity seem to matter more for the local creation of new KISs than for manufacturing. An increase of one more graduates increases the probability of new firm entry by 2.1%, and one more student increases the probability of new firm entry by 2.1%. The number of universities in the region also displays a positive coefficient (2.4%), suggesting

Table 4 Regression results for high and medium-high tech manufacturing-separating graduates and students in different academic fields

	High and medium high tech			
	I	II	III	IV
Social sciences graduates	0.0037 (0.0036)		0.002 (0.007)	
Engineering graduates	0.0149* (0.0076)		0.015 (0.087)	
Social sciences students		−0.004 (0.003)		−0.006 (0.015)
Engineering students		0.009*** (0.003)		0.007 (0.008)
Work force education	−0.4401 (0.4596)	−0.145 (0.432)	−0.649 (0.999)	−0.225 (1.763)
Sales volume per capita	0.0629 (0.0679)	0.067 (0.057)	0.044 (0.624)	0.054 (0.212)
KBE firms	0.3088*** (0.0269)	0.316*** (0.047)	0.313 (0.240)	0.325 (0.318)
Pop. density	0.1228 (0.0797)	0.132*** (0.050)	−0.02 (0.551)	−0.004 (0.217)
Distance to administrative centre	−0.2833*** (0.1006)	−0.269*** (0.079)	−0.09 (0.540)	−0.06 (0.081)
Distance to Oporto	−0.1475 (0.0964)	−0.135** (0.064)	−0.576 (0.531)	−0.582 (0.465)
Distance to Lisbon	−0.1147 (0.0985)	−0.093 (0.060)	−0.025 (1.076)	−0.006 (0.521)
Dummy for years	Yes	Yes	Yes	Yes
χ^2	16.64*	16.64*	500.31***	446.14***
Dummy for distritos	No	No	Yes	Yes
χ^2			4,064.58***	3,137.45***
Dummy for nuts 2	No	No	Yes	Yes
χ^2				40,001.78***
Constant	2.1466 (2.8175)	0.965 (1.761)	−0.064 (1.635)	−1.302 (1.705)
	2,732	2,738	2,732	2,738
	(2,001 zero observations)	(2,006 observations)	(2,001 zero observations)	(2,006 zero observations)
χ^2	1,211.66***	833.60***		104.76***
McFadden R^2	–	0.556	–	0.569
ML R^2	–	0.677	–	0.685
Cragg and Uhler R^2	–	0.779	–	0.789

I, II—zero inflated negative binomial model. III, IV—zero inflated negative binomial model with standard errors adjusted for clustering. Robust standard errors in parentheses
* Significant at 10%; ** significant at 5%; *** significant at 1%

that knowledge spillovers originating in local universities have an impact on entrepreneurial activity in services, opposite to what was found for manufacturing. These results hold when we introduce the regional dummies and adjust the standard errors for regional clustering (columns IV, V and VI). This is likely to be associated with lower set up costs in services when compared with manufacturing. Moreover, these results reflect a significant trend of increasing employment in knowledge-based services (including telecom, financial, insurance and real estate) during this period, as a result from privatisation, de-regulation and increased foreign investment. Also, according to the results of the Community Innovation Surveys (CIS), Portuguese firms have

Table 5 Regression results for the knowledge intensive services

	KIS					
	I	II	III	IV	V	VI
Graduates	0.0215*** (0.0016)			0.018*** (0.002)		
Students		0.0211*** (0.0014)			0.019*** (0.001)	
Universities			0.0243*** (0.0018)			0.021*** (0.002)
Work force education	0.4752** (0.2377)	0.1628 (0.2323)	0.3347 (0.2408)	0.848* (0.454)	0.539 (0.466)	0.719 (0.450)
Sales volume per capita	0.1987*** (0.0366)	0.1859*** (0.0362)	0.1886*** (0.0364)	0.175* (0.104)	0.153 (0.102)	0.162 (0.102)
KBE firms	0.2684*** (0.0500)	0.2684*** (0.0482)	0.2728*** (0.0485)	0.314*** (0.093)	0.307*** (0.086)	0.316*** (0.091)
Pop. density	0.4350*** (0.0183)	0.4430*** (0.0175)	0.4384*** (0.0183)	0.216*** (0.035)	0.212*** (0.032)	0.211*** (0.035)
Distance to administrative centre	−0.1175*** (0.0313)	−0.1452*** (0.0309)	−0.1262*** (0.0313)	0.047 (0.090)	0.02 (0.077)	0.04 (0.082)
Distance to Oporto	0.1116*** (0.0243)	0.1294*** (0.0231)	0.1111*** (0.0242)	−0.298*** (0.090)	−0.304*** (0.078)	−0.314*** (0.084)
Distance to Lisbon	−0.0239 (0.0235)	−0.027 (0.0229)	−0.0304 (0.0233)	0.018 (0.029)	0.031 (0.030)	0.02 (0.030)
Dummy for years	Yes	Yes	Yes	Yes	Yes	Yes
χ^2	131.57***	146.18***	139.01***	28.03***	37.22***	55.58***
Dummy for distritos	No	No	No	Yes	Yes	Yes
χ^2				165.65***	87.75***	68.51***
Dummy for nuts 2	No	No	No	Yes	Yes	Yes
χ^2				175.67***	273.96***	217.32***
Constant	−2.9924*** (0.5604)	−2.3078*** (0.5643)	−2.5261*** (0.5726)	−0.877 (1.768)	0.039 (1.814)	−0.327 (1.740)
Observations	2,738 (772 zero observations)	2,738 (772 zero observations)	2,738 (772 zero observations)	2,738 (772 zero observations)	2,738(772 zero observations)	2,738(772 zero observations)
χ^2	3,819.46***	3,938.57***	3,779.53***	128.79***	119.88***	2,464.95***
McFadden R^2	0.340	0.343	0.341	0.365	0.368	0.365

Table 5 continued

	KIS					
	I	II	III	IV	V	VI
ML R^2	0.828	0.831	0.829	0.849	0.851	0.849
Cragg and Uhler R^2	0.833	0.835	0.833	0.854	0.856	0.854

I, II and III—zero inflated negative binomial model. IV, V and V—zero inflated negative binomial model with standard errors adjusted for clustering. Robust standard errors in parentheses

* Significant at 10%; ** significant at 5%; *** significant at 1%

been significantly more innovative in services than in manufacturing (Bóia 2003), showing higher levels of both R&D and adoption of new technologies. The results confirm hypotheses 1, 2 and 3 for KISs.

Agglomeration effects associated with the local density of incumbents are also significantly positive on entry by new KIS firms. The effect of regional workforce education on entry into KISs displays a positive significant result for the estimations with the number of graduates (columns I and IV). This may suggest that highly skilled labour is likely to recognize and exploit opportunities for new business creation in knowledge-based services. While this surely reflects lower set up costs and barriers to entry in services than in manufacturing, it is also likely to be associated with higher levels of innovation, R&D and new technology adoption in services than in manufacturing which, as was pointed out above, have been a feature of the Portuguese economy. Regional sales volumes, number of firms and population density display the positive effect on entry, as expected. Local demand effects display a positive effect on entry into services, suggesting that new firm formation in services is likely to respond to local market needs. As for the urban accessibility variables, the distance to the Oporto region display positive and significant effects on entry into services, opposite to what was found for manufacturing, which could suggest that regional accessibility to knowledge-based services is important for customers (Holl 2004). The variable measuring distance to administrative centre has a negative significant coefficient. These results change when we introduce the clustering for the region, meaning that these effects disappear once we introduce intra-regional effects.

In Table 6 we observe that, different types of students and graduates gave similar results. The presence of graduates and students in the region has positive effect in entry in knowledge-based services, regardless of the type of studies they undertake. Thus, hypothesis 4 is rejected for knowledge-based services. This result contradicts previous evidence by Cassia and Colombelli (2008) who found that knowledge-intensive service activities are particularly dependent on knowledge in social sciences and are motivated to interact with universities conducting research in those fields, and that research in natural science is less important for this class of firms. On the other hand, our results are in agreement with Audretsch et al. (2004) who found that the number of students in both fields influences significantly firms' locational decision. These authors suggest that tacit knowledge, expressed and incorporated by the number of students highly influences the locational decision, and that students serve as knowledge transmission vehicles from the university where it is created to a firm where it becomes commercialized (Audretsch et al. 2004).

5 Concluding remarks

The purpose of this paper has been to identify regional differences in new firm entry in knowledge-based economic activities, relating those with the local accessibility of knowledge sources, and existence of human capital capable of absorbing available knowledge, using it in the discovery and exploitation of entrepreneurial opportunities. This analysis aims at extending our knowledge of the mechanisms influencing the location choice of knowledge-based firms. Entrepreneurship can be seen as a

Table 6 Regression results for the knowledge intensive services

	KIS			
	I	II	III	IV
Social sciences graduates	0.0210*** (0.0017)		0.016*** (0.003)	
Engineering graduates	0.0099*** (0.0021)		0.014*** (0.003)	
Social sciences students		0.0130*** (0.0019)		0.009* (0.005)
Engineering students		0.0137*** (0.0018)		0.013*** (0.003)
Work force education	0.5490** (0.2397)	0.2014 (0.2318)	0.929** (0.455)	0.766** (0.357)
Sales volume per capita	0.2102*** (0.0370)	0.2258*** (0.0367)	0.181* (0.103)	0.183* (0.106)
KBE firms	0.2671*** (0.0499)	0.2596*** (0.0475)	0.315*** (0.086)	0.321*** (0.079)
Pop. density	0.4255*** (0.0186)	0.4665*** (0.0168)	0.206*** (0.032)	0.244*** (0.041)
Distance to administrative centre	−0.1168*** (0.0312)	−0.1191*** (0.0296)	0.03 (0.087)	0.026 (0.076)
Distance to Oporto	0.0976*** (0.0243)	0.1390*** (0.0224)	−0.297*** (0.085)	−0.232*** (0.064)
Distance to Lisbon	−0.0209 (0.0240)	−0.0146 (0.0234)	0.007 (0.029)	0.039 (0.033)
Dummy for years	Yes	Yes	Yes	Yes
	135.37***	155.19***	33.85***	171.88***
Dummy for distrito	No	No	Yes	Yes
			84.52***	117.11***
Dummy for nuts 2	No	No	Yes	Yes
			200.50***	54.66***
Constant	−2.9253*** (0.5807)	−2.8789*** (0.5479)	−0.064 (1.635)	−1.302 (1.705)
	2,732	2,732	2,732	2,738
	(771 zero observations)	(771 zero observations)	(771 zero observations)	(771 zero observations)
χ^2	4,011.46***	4,319.88***	148.18***	251.08***
McFadden R^2	0.341	0.340	0.366	0.364
ML R^2	0.829	0.828	0.850	0.848
Cragg and Uhler R^2	0.834	0.833	0.854	0.853

I, II—zero inflated negative binomial model. III, IV—zero inflated negative binomial model with standard errors adjusted for clustering. Robust standard errors in parentheses

* Significant at 10%; ** significant at 5%; *** significant at 1%

process of exploiting opportunities that exist in the environment. Thus, the incidence of entrepreneurial activity in knowledge-based sectors should vary across regions according to the pools of innovative opportunities and human capital available in each region, and the existence of human capital capable of recognising and exploiting opportunities.

There are significant differences in new firm formation in knowledge-based sectors among Portuguese regions. Although the number of firms in these sectors increased significantly across all regions over the period under analysis (1992–2002), these differences have, for the most part, persisted. Our study finds that local access to knowledge and human capital plays a significant role in generating differences in entry by new knowledge-based firms across regions, even after controlling for other regional-level factors, such as the size of the local market and agglomeration effects arising from the density of incumbents. However, the pattern of region-specific effects is different for manufacturing and services.

Three different measures of local access to knowledge and human capital were used in this study: (i) the number of universities in the region, which allows us to capture the impact of knowledge-generating R&D and education activities; (ii) the number of graduates in the region; and (iii) number of students in the region. These last two measures capture knowledge embodied in individuals through formal education. Furthermore, average levels of education of the workforce were used to capture more specific levels of human capital, associated with labour market experience and formal education. Finally, we differentiated between specific kinds of human capital, running separate regression for groups of students and graduates in (a) basic sciences and engineering and (b) social sciences.

All measures of local access to knowledge and human capital, number of college students, new college graduates and the local presence of universities play a significant role in driving entry in knowledge-based sectors. Furthermore, the number of students and graduates engaging in technology associated degrees in regions has shown a significant effect in the creation of new firms in knowledge intensive manufacturing. However, this is not true for KISs, where the effect of students and graduates in different academic fields is not significantly altered. This difference indicates that more specific knowledge and human capital are more relevant to manufacturing, while for services it is the regional absorptive capacity that seems more relevant.

However, two sorts of issues differentiating manufacturing from services should be taken into account:

(i) the set up costs for knowledge-based manufacturing are likely to be much higher than for knowledge-based services, meaning that liquidity constraints will be more binding for aspiring entrepreneurs, while local markets are unlikely to be enough to support the required efficient scale;
(ii) innovative activities, including R&D and technology adoption were significantly higher in Portugal for KISs than for high and medium-high tech manufacturing during the period under analysis, so opportunities for new businesses were probably more numerous in services.

These two factors may help explain a striking difference between manufacturing and services: while regional average work force education displays in some cases a non-significant effect on new firm formation in high and medium-high tech manufacturing, this effect is mostly positive on new firm formation in knowledge intensive sectors. This finding suggests that opportunities for new businesses in manufacturing are indeed fewer, and that absorptive capacity associated with human capital may benefit incumbents instead of potential entrants. If manufacturing-specific human capital is relatively scarce, more educated workers should be able to obtain more attractive wage offers by incumbents, thus raising the opportunity cost of starting a new business. This also suggests that, while in knowledge-based services the amount of skilled human capital has reached the levels required for potentially more competitive new businesses (i.e. with greater entrepreneurial human capital) to be started, new firms in knowledge-based manufacturing are more likely to be started by individuals with lower entrepreneurial human capital.

Local competition and transport costs also impact differently on manufacturing and service start-ups. Start-ups in high and medium-high tech manufacturing are less likely to appear in areas farther from large urban centres. This is probably due to the fact that these firms require access to markets that are larger than the local ones, and transport costs are significant enough to drive firms to locate closer to larger urban centres. Start-ups in KISs are more likely to locate farther from the largest urban centres, suggesting that local markets represent a significant opportunity for new firms in these sectors. However, proximity to local (district-level) urban centres has a negative impact on regional start-up numbers.

By focusing the analysis on the role played by local knowledge sources, and absorptive capacity embodied in local human capital, this paper adds to the still scarce literature addressing these factors as determinants of new firm entry into regions. A further contribution is provided by focusing specifically on knowledge-based sectors, which have shown greater potential for employment creation in the medium and long run. The results obtained, particularly with regard to differences between manufacturing and services, offer significant insights for policy-makers. In particular, while the local development of knowledge-based manufacturing seems to require more investment in education of specialised human capital and in R&D activities that generate knowledge spillovers, development of knowledge-based services seems to be undergoing a more advanced stage of development, in which competitiveness and efficiency are more likely to arise from local competition and innovative activity.

Future work needs to concentrate in extending the analysis through the use panel data methods applied to count data models, while looking specific at treatment and policy effects arising from the creation of new knowledge sources (such as a new university) in specific regions.

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