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Regional competitiveness, university spillovers, and entrepreneurial activity

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Abstract This study examines the impact of regional competitiveness on the innovative activity of entrepreneurial firms. Based on a unique and hand-collected dataset of publicly listed high-technology start-ups and university regions, this paper tests how regional competitiveness and university spillovers affect the innovation behavior of entrepreneurial firms. The results provide strong evidence that regional competitiveness and university spillovers are strong complements in fostering innovation activity of entrepreneurial firms. However, the results also raise the question whether incentives for universities and their actors might lead to crowding out effects.

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1 Introduction

The production, acquisition, absorption, reproduction, and dissemination of knowledge are seen as the fundamental characteristics of contemporary competitive dynamics, likewise in fostering innovative activity (Sorenson and Audia 2000; Baum and Sorenson 2003; Varga 2000; Stuart and Shane 2002; Anselin et al. 2000; Santoro and Chakrabarti 2002). One result of this area of research is that some locations experience stronger economic performance than others, especially in fostering entrepreneurial activity (Audretsch et al. 2006; Porter 2003; Van Praag and Versloot 2007).

The theoretical background for empirical findings is provided by the endogenous growth theory (Romer 1986, 1990; Lucas 1988). This theory explains innovation as an industrial combination of labour and knowledge (i.e. firm R&D) on the one hand and as a combination of human capital and knowledge through university research on the other hand; knowledge production is a function of university and industry innovation. At the same time the major part of knowledge production cannot be effectively expressed using symbolic forms or representation, but remains embedded in relatively immobile human capital (Kogut and Zander 1992; Gertler 2003). Tacit knowledge cannot be easily transferred over large distances or bought via the market. This gives rise to regional knowledge production as the prevalent economic explanation of the competitiveness of regions (Griliches 1979; Pakes and Griliches 1984; Levin et al. 1987).

Past research points out that the main source of tacit knowledge is research intense universities (Jaffe 1989; Jaffe et al. 1993; Acs et al. 1992, 1994) as producers of human capital and research which "spill over" (Arrow 1962a) to the regional industry, especially innovative firms. These firms in turn use this knowledge to create new products and foster regional competitiveness (Anselin et al. 1997; Acs et al. 2002; Rip 2002; Fritsch and Slavtchev 2005; Drucker and Goldstein 2007). Without doubt, the existence of universities augments regional competitiveness to foster entrepreneurial activities and regional growth. However, there is only scarce evidence about the separate impact of either regional endowment and the existence of universities on entrepreneurial activity. In this paper we fill this gap by analyzing the separate impact of universities and regional endowments on the innovation behavior of young and high-technology intensive firms.

We argue that there are some key questions regarding the location decisions of firms which remain rather unexplored. While research has identified the important role that universities play in generating knowledge spillovers on the one hand and regional competitiveness on the other hand, the combined importance of both factors in transmitting knowledge spillovers remains relatively unexplored. Furthermore, anecdotal evidence suggests that the presence of a large university is a necessary element in the social and cultural climate that creative individuals demand. Thus, three hypotheses are tested. The first hypothesis is focused only on the impact of regional competitiveness on innovation behavior of entrepreneurial firms. The second only points out university research expenditures and university spillover shaping innovation behavior of firms. Finally, the third hypothesis states that both regional competitiveness together with research university expenditures significantly shape the innovation behavior of firms.

The purpose of this paper was to address these questions focusing on how regional competitiveness and university spillovers shape the innovation behavior of entrepreneurial firms. This is realized by explaining the innovation behavior of entrepreneurial firms—as measured by firm patents (endogenous variable)—as a function of the regional competitiveness, proximity to the next university and the research outputs of this university. Thereby not only the combined knowledge production of industry and research, but also the characteristics proposed by endogenous growth theory can be identified separately.

This paper is based on a hand-collected dataset of all 475 IPOs in Germany over a ten-year period (1997–2007). In particular, compelling evidence is found that neither regional competitiveness alone nor the research output of close universities alone can explain the patenting activities of entrepreneurial firms. However, combining both sources of spillovers, the results clearly show that firm behavior is significantly shaped by research intensive universities but also by regions with above-average endowments. Thus, the results confirm studies pointing out that distance matters for university spillovers. Especially research output measured by citations positively shapes the number of firm patents. In contrast, any significant impact of the number of university patents on firm patents could not be found. These results are in line with the sectoral differentiation of industry innovation and university research as suggested by endogenous growth theory and at the same time confirm the synergies of both sectors in producing new knowledge. These beneficial effects on fostering entrepreneurship as the predominant agent of innovation (see Acs and Plummer 2005; Malchow-Møller et al. 2011; Müller 2006) are moderated by public policy. We find that a liberal (i.e. market-oriented) government on federal state level promotes entrepreneurship while social-democratic (i.e. interventionist) government impedes entrepreneurship. Finally, the results also shed some light on the question of whether universities might not only foster entrepreneurial activities but also compete with young firms.

The findings also indicate that regional competitiveness significantly shapes entrepreneurial behavior. Measures like the GDP/employee or population density explain significantly the number of patents of a firm located in the respective region. One of the most striking findings however is the number of firms founded in that region or, what Audretsch and Keilbach (2004) call, entrepreneurial capital. The results also reflect the structural change towards an entrepreneurial economy as proposed by Audretsch and Thurik (2001).

The remainder of the paper is organized as follows: Sect. 2 summarizes the literature and introduces the testable hypotheses raised in this paper, Sect. 3 contains a description of the database and the estimation techniques, and the empirical results are presented in Sect. 4. The last section presents a summary and conclusions.

2 Regional competitiveness, firm location and innovative activity

The point of departure is that the location decision of firms in an imperfectly competitive industry is not random, but based on two considerations, namely, the cost of market access and growth opportunities as well as quality and the cost of inputs at each location. The better part of competitiveness of knowledge-based and high-technology firms is determined by the latter factor. In this paper it is argued that high-tech firms chose their location based on their assessment of regional competitiveness (productivity, innovations). Therefore, one should be able to predict the innovative activity of young high-tech firms by using indicators of regional competitiveness, i.e. highly innovative firms settle in highly competitive regions.

In microeconomic theory the work of Solow (1956) proves the existence of a latent variable other than technology (K) and labour (L) in (regional) economic growth. The endogenous growth model (Romer 1986, 1990) identifies this variable as new knowledge embedded in human capital (H). New knowledge itself consists of innovation (Arrow 1962b) and education (Uzawa 1965) and is a result of the interactive learning processes. New knowledge is created by combining existing knowledge (A) with human capital (H*A). Innovation is formed by employing labour (L) to existing knowledge (L*A). Output (Y) is produced by applying existing technology (K) to the aforementioned factors:

$$Y = (\mathrm{H} * \mathrm{A})^{\alpha} * (\mathrm{L} * \mathrm{A})^{\beta} * \mathrm{K}^{\eta}$$

Romer (1990) distinguishes three societal domains with unique roles in this production process. Universities produce new knowledge through research and education (H*A), industrial R&D creates innovation (L*A) and industrial production uses technology (K) to create goods. These distinct domains are interconnected by knowledge spillovers. Economically relevant knowledge is produced as a combination of university research and industry R&D. The better the regional endowment with innovative industry and universities, the higher is the innovative activity. As innovation is a main driver of productivity, regional competitiveness can be interpreted as a direct effect of the regional knowledge production and spillovers.

The view that knowledge spills over from universities to firms who commercialize that knowledge is supported by theoretical models (Romer 1986, 1990; Krugman 1991; Grossman and Helpman 1991) and tested by a number of empirical studies (Jaffe 1989; Jaffe et al. 1993; Acs et al. 1992, 1994; Audretsch and Feldman 1996; Audretsch and Stephan 1996; Audretsch and Lehmann 2005; Audretsch et al. 2005). In the empirical literature, the sources of knowledge spillovers are identified by the number of patents (Jaffe 1989), the number and quality of citations (Audretsch and Feldman 1996), local proximity to universities (Audretsch and Lehmann 2005), the endowment of universities (Audretsch et al. 2005) or the kind of knowledge (Audretsch et al. 2004), among others. According to this literature it is hypothesized that all inputs provided by research universities as well as local proximity should enhance the number of patents of firms located in this region.

The geographical approach to knowledge production is not only explained by the local proximity of research universities but also by the regional industry. In recent years, the expression of regional competitiveness entered the literature (Boschma 2004), which shows that territorial competition shaped from countries to smaller geographic regions. These compete in a variety of instances, e.g. the ability to attract capital, the ability to attract highly-skilled employees and entrepreneurs, and the ability to attract knowledge and innovative activity. Regional competitiveness appears to be neither the simple aggregation of firms nor a weighted disaggregation of the national economy. Boschma (2004, p. 1005) clearly points out that "like market shares shifting between firms, successful regions will increase their relative share in the (national or world) economy at the expense of lagging region". While firms directly compete in market shares, regions are more or less directly in a state of competition trying to attract creative talent and investments from elsewhere (Florida 2002). However, successful regions as a relevant entity should affect the behavior and performance of local firms (Boschma 2004; Mueller et al. 2008; Beaudry and Swann 2009; Wennberg and Lindqvist 2010).

The approach of regional competitiveness has demonstrated the importance of the spatial dimension in analysis of the innovative process. There now exists a large body of literature showing the relevance of industrial districts (Becattini 1990; Rocha and Sternberg 2005), regional labour markets (Fritsch 1997), geographic location of R&D (Piergovanni and Santarelli 2001) or the concept of social capital (Putnam 1993). Especially the latter influenced a new body of literature, pointing out the importance of investments in social capital. Audretsch and Keilbach (2004) followed this approach by pointing out the importance of a region's entrepreneurship capital as a driving force in explaining the innovation behavior of entrepreneurial firms.

The prediction that innovative activity favors those with direct access to knowledge-producing inputs does not necessarily apply to all cases (Link and Ruhm 2011). In this context, innovative studies benefit if they take into consideration a unit of observation which also comprises the spatial dimension of the system of innovation or the local endowments in which each firm belongs. This resulting geographical approach to knowledge production was thus originally developed by Jaffe (1989). Based on this approach it is differentiated among the two sources of knowledge spillovers, i.e. research expenditures undertaken by research universities and the innovation capacities of industries in the same region. These knowledge spillovers are assumed from universities, regions or both. Such spillovers serve as a source of knowledge, creating the entrepreneurial opportunities to generate innovate outputs.

To sum up, three testable hypotheses are formulated based on the above cited literature. The first hypothesis (H1) is built on the literature of local proximity to research intense universities and the impact on individual entrepreneurial companies. This literature argues that the innovation behavior of entrepreneurial firms is connected to the university knowledge production (Audretsch and Lehmann 2005; Colombo et al. 2010). Local innovation activity by entrepreneurial firms is positively affected by knowledge spillovers from universities.

H1 "University Spillover Thesis": Research expenditures by local universities significantly increase the innovation behavior of entrepreneurial firms.

The second hypothesis (H2) summarizes findings from the broad literature highlighting the impact of regional and industrial endowment on entrepreneurial firms (see e.g. Boschma 2004; Fritsch 1997; Audretsch and Feldman 1996). This hypothesis states that innovation behavior of entrepreneurial firms is shaped by regional specific variables, like the existence of entrepreneurship capital (Putnam 2003; Audretsch et al. 2006, p. 60ff).

H2 "Regional Innovation Capacity Thesis": Superior regional endowment significantly increases the innovation behavior of entrepreneurial firms.

Finally, the third hypothesis (H3) is built on the above-mentioned literature on regional competitiveness, highlighting the complementary behavior of both, the existence of excellent universities and superior regional endowment, which foster entrepreneurial growth. These works showed that knowledge produced by universities is captured within the regional environment and results in enhanced entrepreneurial activity.

H3 "Regional Competitiveness Thesis": Only the combination of research expenditures by local universities and superior regional endowment significantly increases the innovation behavior of entrepreneurial firms.

3 Data and measurement

3.1 Sample selection

To test the influence of regional competitiveness and university spillovers on entrepreneurial activity, we used a unique and hand-collected dataset of high-technology German IPO firms. Our initial dataset compiled all IPOs of German issuers, as identified by their ISINs, in segments of *Deutsche Boerse AG* (German Stock Exchange) in the period from 1997 to

2007. Containing 433 IPOs in segments of *Deutsche Boerse AG's* regulated market, our initial sample covered about 90% of total regulated market IPOs in Germany in the respective time period. Additionally, all 42 firms listed in *Deutsche Boerse AG's* primary statistics for this time period that had their IPOs in the open market segment were included. From these 475 observations, all banks (3 firms), holding companies (7 firms) and established firms founded more than 8 years (the median age in the whole dataset) before an IPO and employing more than 1,000 employees (236 firms) were dropped. This led to a sample of 229 firms defined as young and high-tech entrepreneurial firms, including highly innovative industries, like biotechnology, medical devices, life sciences, e-commerce, and other high-technology industries which represent the knowledge-based economy. The basis for using the time period 1996–2007 was because in the years prior, IPOs were a rather seldom phenomenon in Germany and only large and established firms put their shares public. Moreover, no IPO was observed from 2007 until March 2010. This may lead to a selection bias, since IPO firms may represent rather successful operating companies is known (see e.g. Audretsch et al. 2006). However, in contrast to private entrepreneurial firms, an IPO has to publish information to the public. This allows gathering detailed information about the firms.

3.2 Variables and measurement

This company dataset was pooled with indicators of regional competitiveness and university characteristics within the respective region to account for the impact of industry and research on regional entrepreneurship. As in previous studies (see e.g. Jaffe 1989; Acs et al. 1992), the relationship across geographical areas and university research expenditures is examined as well as private innovation output by entrepreneurial firms in terms of patent counts. Although patents may be a rather questionable measure, "a patent after all represents a minimal quantum of invention that has passed both the scrutiny of the patent officer as to its novelty and the test of the investment of effort and resources by the inventor and his organization" (Griliches 1990, p. 1669). The crucial innovative input is new technological knowledge generated by R&D, and the relevant innovative output is technological knowledge resulting in patent innovations (Griliches 1979, 1984). In this way, it should be expected that firms differ in their number of patents by their location and therefore their access to sources of inputs. The number of patents is taken from the German patent office (Deutsches Patentamt).

Firm location is often measured by geographic districts, which are comparable to the Standard Metropolitan Statistical Areas (SMSA), often used in regional studies for the United States (Varga 2000). The regional level of analysis is based on labor market regions (LMRs), sometimes also called travel-to-work areas. LMRs are constructed to represent regions of common economic activity by merging administrative districts based on human capital commuting in and out of these counties (hence travel-to-work areas). In this way LMRs are mapping the mobility of human capital in space and integrate intraregional geographic effects, while confining interregional spillover effects. LMRs are used according to the construction by Eckey et al. (2006) through factor analysis with oblique rotation, and a constraint of a one-way commuting time of 60 min, resulting in 150 LMRs based on 440 administrative districts in Germany. These LMRs are not biased by administrative or political considerations. Hence, choosing LMRs as the level of analysis not only represents the geographic dispersion of economic activity, but also controls for the economic geography of regions.

3.2.1 Regions and regional competitiveness indicators

Next, variables indicating regional competitiveness are introduced. As noted above, region is captured by labour market regions (LMR). The impact of regional competitiveness on entrepreneurial innovation is measured by employing proxies for industrial spillovers, regional productivity, industry structure, innovative capacity of the industry, entrepreneurial capital, and political and historical influences. Unspecific (intra- and inter-industrial) spillovers are accounted for by population density (inhabitants per square kilometer) as suggested by the urbanization economics literature (Henderson 1983, 1986; Glaeser et al. 1992; Glaeser 1999). Regional productivity is not measured by GDP per capita (the usual control for productivity in entrepreneurship literature, e.g.

Feldman et al. 2002; Powers and McDougall 2005) but as GDP per employee to correct for variations in population and labor market structure. At the same time, industrial structure is controlled for by decomposing the regional GDP into the gross value added per capita (GVA/Capita) by industry (GVA/Capita Industry) and industrial services (GVA/Capita Services). To measure the innovative activity of the regional industry the number of industry patents per year is used. As shown by Greif et al. (2006), those are highly correlated ($r = 0.956$) with industrial R&D spending at the level of administrative regions. Regional R&D spending has been found to be a relevant measure of regional innovative competitiveness (Feldman et al. 2002; Lindelöf and Löfsten 2004; Link and Siegel 2005). Empirical evidence suggests that technology entrepreneurs interact creatively and thus prefer to be located in a region in which entrepreneurs are concentrated. Hence, the number of new businesses per 1,000 inhabitants is used to factor in the regional entrepreneurial capital.

Finally, regional impacts of federal state level economic policy is controlled by using a dummy variable for this area governed by the social democrats (SPD, known for their non-liberal economic policy) but also for political changes (Change). In contrast, Christian Democrats (CDU) are highly interested in fostering economic and entrepreneurial activities and invest more money in start-up projects or regional R&D. For example, in the state of Bavaria, they directly support university–industry links as well as foster cooperation across large incumbent firms and entrepreneurial firms (see Hülsbeck and Lehmann 2007). As a consequence, it can be expected that entrepreneurial innovation behavior is also shaped by the kind of politics in the respective area. Possible historical impacts of the former German Democratic Republic are captured by a dummy for regions in 'East Germany'. All data, excluding the number of industry patents, have been collected by using the regional statistics database of the German Federal Statistical Office. Data of industry patents were calculated using the German Patent Atlas by Greif et al. (2006).

3.2.2 University spillovers

Now, variables to measure quantity, quality and spillover effects from all the German universities with science and or technology departments ($n = 66$) are introduced. University spillovers could be defined as an externality accessed by firms, for which the university is the source of the spillover but not fully compensated (Harris 2001). Due to the fact that firms access external knowledge at a cost that is lower than the cost of producing this value internally or of acquiring it externally from a larger geographic distance (Harhoff 2000), they will exhibit higher expected profits. The cost of transferring such knowledge is a function of geographic distance and gives rise to localized externalities (Siegel et al. 2003). As previous research shows, the production of knowledge and thus spillovers by universities is significantly shaped by quantity and quality parameters (see Varga 2000; Henderson et al. 1998; Hall et al. 2003; McWilliams and Siegel 2000; Audretsch and Stephan 1996, 1999; Zucker et al. 1998). To capture the spillover mechanism, this literature will be followed measuring quantity and quality effects by the number of articles by scientists of a university, the citations, third party funding, the number of university patents and the number of students. To control for size effects, based on the empirical literature the ratios per researcher are used. All university data come from the research ranking of German universities (Berghoff et al. 2006). To control for the introduction of the German copy of the Bayle-Dole Act (Arbeitnehmererfindungsgesetz) in 2002, the number of university patents before 2001 (#patents 97–01) and after 2001 (#patents 02–06) are included. As previous research shows, the number of university patents increased significantly in the United States after the Bayle-Dole Act in 1980 (see Henderson et al. 1998, for quantity effects, but also Mowery and Ziedonis 2002 for qualitative effects).

As Arrow points out, "learning […] takes place during activity" (1962b, p. 155) and thus leads to path dependencies; it will be controlled for learning effects in patenting. As previous studies show, this experience could be expressed by time effects (Coupé 2003; Friedman and Silberman 2003). Ergo, the age of the first patent application is included to control for learning effects and in this manner path dependencies in patenting. However, universities in Germany differ largely in two aspects: Whether they have a medical or an engineering department. Consequently, dummy variables indicating universities with a large department in medicine (Medicine Faculty) or engineering (Engineer Faculty) are used.

As noted earlier, spillover effects diminish over time and distance. Thereupon, as Jaffe (1989) points out, geographical location is important in capturing the benefits of spillovers when the mechanism of knowledge is informal conversation, as is the case of tacit knowledge. Then, "…geographic proximity to the spillover source may be helpful or even necessary in capturing the spillover benefits" (Jaffe 1989, p. 957). Shane (2001a, b) explores the determinants of proximity to MIT (Massachusetts Institute of Technology) on new firm formation. His main finding is that universities create technological spillovers, which could be exploited by the formation of new firms. Thus, the limited geographic reach of such channels for the exchange of information and know-how is assumed to be one of the leading causes of the impact of geographic proximity. That is why geographical proximity enters in the analysis. To test the impact of universities on a firm's location decision, the distance to the closest university as the dependent variable is taken. Since universities in Germany are more geographically concentrated compared to the United States, there is the need for a measure which is sensitive to small variations. The distance is measured in kilometers using the online database of the *German Automobile Club* (www.adac.de). All firms located within a radius of 2.5 km are classified as belonging in the distance category of 1 km—the smallest value. While some universities, like the University of Konstanz, are very small in their geographic expansion, others, like the universities of Munich are quite large. To control for this variation, the closest distance towards a university is measured with 1 km but including all firms located within the inner circle of 2.5 km (the median of the geographic expansion of universities) as located also closest towards a university.

3.3 Research methods

The number of firm patents as a function of regional competitiveness, the existence of a university, university output, as well as industry and firm specific variables is empirically modeled. As the endogenous variable is discrete rather than continuous and cannot become negative, linear regression models result in biased estimations (see Kennedy 2003, p. 48). In early empirical research this problem was bypassed by using logarithms of the native indicators to transform discrete variables into continuous ones while buffering nonlinear effects. However, this procedure does not account for unobserved heterogeneity among units or correlated error terms. To obtain unbiased estimations one can use a Poisson regression model. This model bases on the Poisson distribution, which predicts independent rare events (e.g. a patent grant). However, note that a Poisson model assumes equality between the mean and variance of the dependent variable. Specification tests for overdispersion (Cameron and Trivedi 1997) reject the Poisson as the appropriate distribution for the data used in this study. To relax this assumption we use negative binomial distribution, a discrete probability distribution of the number of successes in a row of Bernoulli trials. For example, if one tosses a coin until he gets five 'heads' the number of 'tails' occurring in this process follows a negative binomial distribution. As can be inferred from this simple example the negative binomial distribution does not assume the independence of trials—the more 'heads' in a row one gets, the more likely it becomes to get 'tails'—and can therefore account for contagion effects in the sample (Johnson et al. 2005). In the present case one can assume learning effects in a way that firms with high patent counts are more likely to get additional patents. This illustrates the violation of the linearity assumption of ordinary least squares regression as well. In summary, the negative binomial regression model is the only model allowing for non-linearity, contagion, unobserved heterogeneity (Gourieroux et al. 1984) and correlated standard errors (Long 1997) at the same time. Nevertheless the empirical models presented in the following subsections were tested against alternative models using the 'countfit' procedure suggested by Long and Freese (2006, p. 409) and found the negative binomial regression model superior to the Poisson regression, zero inflated Poisson regression and zero inflated negative binomial regression for all tests (Bayes Information Criterion, Akaike Information Criterion, Vuong-Test, likelihood-ratio-test).

Four different models were estimated. Model (I) includes only industry variables and firm size to explain the number of patents. Model (II) expands the first specification by including variables measuring regional competitiveness. In Model (III) the impact of university spillovers on the number of firm patents is estimated. Then, in the forth specification (Model IV) the variables jointly together are estimated.

Model (I): Firm patents $= f(\text{Industry, Size}) + \text{Error}$

Model (II): Firm patents $=$

$f(\text{regional competitiveness, Industry, Size}) + \text{Error}$

Model (III): Firm patents $=$

$f(\text{university spillovers, Industry, Size}) + \text{Error}$

Model (IV): Firm patents $=$

$f(\text{regional competitiveness, university spillovers, industry, size}) + \text{Error}$

3.4 Descriptive statistics

Table 1 presents and summarizes the descriptive statistics. On average, a firm owns 26 patents. However, as shown by the standard deviation, this variable is highly skewed, with a maximum value of 475 patents. A closer look at the "Firm & Industry Variables" shows an average entrepreneurial firm in our data set is located within a radius of about 8 km away from the next university and employs about 240 employees.

The first rows contain the variables indicating regional competitiveness (regional variables) in labor market regions. The variables differ considerably across the regions. On average, there live about 500 people/km^2 with a maximum value of more than 2,500 and a minimum value under 50 people/km^2. There are also large differences in GVA/Capita values or in new business creation—or entrepreneurial capital.

Also, public universities in Germany differ significantly in their research outputs and expenditures. While there are universities without third party funding, only about four publications per researcher and no registered patent until 1997, there also exists some excellent research universities with more than 200,000€ funding per researcher or about 150 citations per researcher.

4 Empirical evidence

The empirical results from the negative binomial regressions are presented in Table 2. In the first specification (Model I), only industry dummies and firm size are included to explain the number of patents owned by firms. The results, as depicted in column 2, clearly show that industries differ significantly in their patent activity. While observing a significant and positive coefficient in high-tech industries like biotech or medicine and life sciences, a significant lower patenting intensity is observed in the Media & Entertainment industries or consumer goods industries. Interestingly, firm size, as measured by the number of employees, remains insignificant.

Next, the first hypothesis (H1) is tested by Model (II). This regression model only includes the variable of regional competitiveness. While the industry dummies remain significant as in Model (I), none of the regional variables shows a significant impact in explaining the number of firm patents. This leads to rejection of the first hypothesis concluding that regional competitiveness as expressed by the set of variables does not show any significant impact on a firms' innovation behavior. This result confirms previous findings that firm behavior is not necessarily shaped by the local endowments alone (Audretsch and Fritsch 2003).

Then, it is up to control for the second hypothesis (H2) that university research expenditures significantly shape the number of firm patents and include university specific variables to measure the spillover effects of the closest university. The results from Model (III) are depicted in column 4. As before, the regression results cannot find empirical support for the hypothesis that university research expenditures significantly shape the innovation behavior of entrepreneurial firms. There is only one variable which fits to the hypothesis. The dummy variable indicating a technically oriented university enters the regression positively while the existence of a medicine faculty has no statistically significant impact. However, the results show some puzzling findings. First, third party funding seems to lower significantly the innovation behavior of entrepreneurial firms. In the last decade, third party funding is one of the major goals for university professors. Their individual and personnel income significantly increases with the amount of third party funding acquired, both by higher salaries paid by the universities and directly linked transfers from the industries. Since entrepreneurial firms often lack substantial financial resources, large incumbent firms are more attractive as research partners. Thus, it may be more attractive to professors to compete with entrepreneurial firms. Their laboratories are mostly paid for by the tax payer or funds from larger firms.

Table 1 Descriptive statistics

Statistics	Mean	Standard deviation	Min	Max
Endogenous variable				
Firm patents	26.86	70.13	0	475
Regional variables				
Population density	510.914	391.618	45.92326	2508.396
GDP/employee	62.655	9.644	42.93745	76.974
GVA/capita industry	7.529	2.432	3.416305	14.922
GVA/capita industry services	9.978	5.051	3.126754	17.934
Industry patents	1696.843	1487.652	4.947883	4775.197
New businesses	10.155	1.604	5.98133	13.251
Country policy (dummy)	0.359	0.481	0	1
East Germany (dummy)	0.051	0.220	0	1
University variables				
Medical faculty (dummy)	0.561	0.498	0	1
Engineer faculty (dummy)	0.328	0.471	0	1
Students/researcher	11.862	8.338	13.777	37.835
Publications/researcher	8.398	5.574	4.172	17.313
Citations/researcher	66.141	53.004	9.840	147.699
Third party funding/res.	109348.000	61058.560	0	202619.000
Age of first patent	9.247	6.683	1	26
Number of patents 97–01	12.859	33.245	0	325
Number of patents 02–06	32.056	38.233	1	387
Firm & industry variables				
Distance to university	8.601	15.153	1	100
Company size	240.576	232.986	1	964
E-Commerce	0.086	0.281	0	1
Media & entertainment	0.126	0.333	0	1
Services (non IT)	0.086	0.281	0	1
IT-components	0.056	0.230	0	1
Finance	0.096	0.295	0	1
Biotech	0.081	0.273	0	1
Medical engineering	0.040	0.197	0	1
Old industries	0.091	0.288	0	1
Consumer goods	0.005	0.071	0	1
Other technologies	0.045	0.209	0	1

They also have superior access to the critical resource of excellent researchers. The negative impact of the year of the first university patent shows that universities with long experience in patenting their inventions may compete directly with entrepreneurial firms. Then, third party funding by the industry may lead to crowding out effects of entrepreneurial innovation behavior. While the dummy variable indicating a medical university enters the regression insignificantly, the dummy variable indicating the existence of an engineering faculty shows a positive and significant impact. This result reflects the long tradition of German universities in engineering.

The number of firms' patents is also negatively shaped by distance, which confirms earlier studies (Audretsch et al. 2005) that knowledge spills over to firms located closer to the source of knowledge. In this specification, firm size shows a positive and

Table 2 Empirical results

Endogenous variable: number of firm patents	Model I			Model II			Model III			Model IV		
Regional variables												
Population density				0.0004	(1.10)					**0.0010**	**(2.09)**	**
GDP/employee				0.0801	(1.30)					**0.1301**	**(2.26)**	**
GVA/capita industry				−0.1250	−(0.81)					−0.1454	−(0.95)	
GVA/capita industry services				−0.1639	−(1.01)					**−0.4866**	**−(3.04)**	***
Industry patents				−0.0004	−(0.61)					0.0006	(0.81)	
(Industry patents)^2				0.0000	(0.21)					0.0000	−(1.55)	
New businesses				1.1102	(0.94)					**2.6027**	**(1.81)**	*
(New businesses)^2				−0.0465	−(0.74)					−0.1101	−(1.43)	
Country policy (dummy)				−0.4455	−(0.82)					**−1.1843**	**−(1.86)**	*
East Germany (dummy)				−0.5483	−(1.12)					−0.4319	−(0.90)	
University variables												
Medical faculty (dummy)							0.8095	(1.05)		**1.3822**	**(1.95)**	*
Engineer faculty (dummy)							**1.3202**	**(3.16)**	***	**1.3815**	**(2.52)**	**
Students/researcher							−0.0171	−(0.68)		**−0.0596**	**−(2.07)**	**
Publications/researcher							−0.0172	−(0.15)		−0.0603	−(0.52)	
Citations/researcher							0.0104	(0.93)		**0.0501**	**(3.61)**	***
Third party funding/res.							**−0.0001**	**−(1.92)**	*	**−0.0001**	**−(2.94)**	***
Age of first patent							**−0.0596**	**−(1.68)**	*	−0.0458	−(1.06)	
Number of patents 97–01							−0.0119	−(0.66)		−0.0208	−(1.19)	
Number of patents 02–06							0.0144	(0.83)		0.0186	(1.16)	
Firm & industry variables												
Distance to university							**−0.0148**	**−(1.69)**	*	0.0068	(0.49)	
Company size	0.0017	(2.27)					**0.0017**	**(1.87)**	*	**0.0015**	**(1.89)**	*
E-commerce	−0.6378	−(0.86)		−0.3452	−(0.40)		−0.5436	−(0.79)		−0.1619	−(0.22)	
Media & entertainment	**−3.8237**	**−(4.98)**	***	**−3.3990**	**−(3.89)**	***	**−3.6941**	**−(4.81)**	***	**−3.0462**	**−(3.42)**	***
Services (non IT)	**1.4000**	**(2.39)**	**	**2.1376**	**(2.57)**	**	**1.8541**	**(3.21)**	***	**2.7709**	**(3.57)**	***
IT-components	**1.7727**	**(2.20)**	**	**2.1815**	**(2.97)**	***	**1.4502**	**(2.35)**	**	**1.3982**	**(2.88)**	***
Finance	**−16.2466**	**−(36.85)**	***	**−17.6386**	**−(30.94)**	***	**−16.6555*****	**−(24.82)**	***	**−19.407**	**−(32.81)**	***
Biotech	**3.2151**	**(8.16)**	***	**3.7033**	**(7.38)**	***	**3.3879**	**(7.95)**	***	**3.8807**	**(8.02)**	***
Medical engineering	**2.4132**	**(4.41)**	***	**2.9098**	**(4.39)**	***	**2.7621**	**(5.10)**	***	**3.2146**	**(5.06)**	***
Old industries	**2.3824**	**(5.04)**	***	**3.0530**	**(6.21)**	***	**2.3120**	**(4.15)**	***	**2.5450**	**(4.28)**	***

Table 2 continued

Endogenous variable: number of firm patents	Model I			Model II			Model III			Model IV		
Consumer goods	**−16.1646**	**−(15.22)**	***	**−17.1957**	**−(14.80)**	***	**−17.7592**	**−(14.17)**	***	**−22.1043**	**−(16.10)**	***
Other technologies	**2.5203**	**(4.53)**	***	**2.9580**	**(4.56)**	***	**2.5339**	**(3.70)**	***	**3.8980**	**(5.21)**	***
_cons	**0.7480**	**(2.03)**	**	−8.2892	−(1.31)		0.7124	(1.48)		**−17.8914**	(−2.23)	**
PseudoLL	−462.757			−458.770			−456.610			−447.1057		

Values given as estimated negative binomial coefficients. Absolute *z*-values in parenthesis. Bold values are statistically significant:

* Statistically significant at the 10 percent level

** Statistically significant at the 5 percent level

*** Statistically significant at the 1 percent level

significant impact, indicating that the number of patents goes in line with firm size and experience effects of universities.

Finally, the third hypothesis (H3) is tested in that both research intense university and regional variables together shape the innovation behavior of firms. Thus, in the fourth specification (Model IV), all variables in the regression are included. In contrast to the previous regressions, now, some variables indicating regional competitiveness and university research expenditures enter the regression significantly. This could be interpreted as regional competitiveness and university output being strong complements in fostering entrepreneurial activity. A positive and significant influence of the population density and the GDP per employee is observed. High population density is associated with lower costs of communication by closer relationships and network effects. The negative and significant sign of the GVA (gross value added) in the service sector reflects that patenting activities in this are lower compared to the industrial sector. The number of start-ups enters the regression positively and highly significant. This variable reflects the entrepreneurial capacity of regions or the "entrepreneurial culture" (Audretsch and Keilbach 2004). Entrepreneurial culture reflects such features as the availability and access to capital, regional policy and incentive programs to support and stimulate entrepreneurial start-up, the support of network programs among others. Finally, a negative and significant impact of the policy variable is observed. This policy variable replaces the variable indicating East Germany as a significant control variable found in earlier studies. Entrepreneurship policy like supporting and providing networks, local attitudes towards "entrepreneurs" or incentive programs to foster and stimulate transfer programs differ significantly among the two major parties in Germany, i.e. the Socialist Democratic Party and the Christian Democratic Party (see e.g. Hülsbeck and Lehmann 2007).

While the variables indicating regional competitiveness only show a significant impact in the joint estimation with the university variables, the latter remain significant in the regression. As has been confirmed by Hülsbeck and Lehmann (2010), these results point to a coevolution of region and university. The coefficients of the dummy variables indicating a medicine faculty and an engineering faculty show a highly significant impact on firm patents. Also, the number of citations enters the regression significant positively now. The negative impact of the number of students/researchers points out that researchers are more engaged in teaching and less in doing research. In contrast to the United States or the United Kingdom, where a kind of labour division across lecturers and research researchers can be observed, in Germany professors as well as PhD candidates or post-docs, which are paid by the public hand, have to teach up to 10 hours per week. Thus, an increase in the number of students per researchers lowers the capacity for doing research. As before, the coefficient of the variable third party funding per researcher remains negative and significant. As explained above, it must be assumed that this finding may be a hint to crowding out effects through a change in the incentive system. Finally, a positive and significant impact of citations per researchers on the patenting behavior of firms is to be observed. This result confirms other findings (Zucker et al. 1998; Audretsch et al. 2005) that research intensive universities provide positive spillover effects to high technology firms.

As for most papers, some limitations of the present analysis need to be noted. The main limitations of the study come from the characteristics of the dataset. First, the analysis relies on a sample of IPO firms, which, as such, can be viewed as a positive selection of successful entrepreneurial firms. This may limit the results to IPO firms. However, those firms are the most dynamic firms in the regional area showing the highest growth rates and impact on regional growth (see e.g. Colombo et al. 2010). Furthermore, the sample is restricted to firms younger than 8 years—the median value of the total sample. This selection bias towards younger firms is intended. The most serious problem of this work is the use of patent counts as a proxy for intellectual capital and technological capabilities. Although other studies also rely on patent counts, this is by far not satisfying. In a famous survey, Griliches (1990) criticizes the use and abuse of patent numbers as indicators for innovation behavior or technological indicators: Not all inventions are patentable, not all inventions are patented and finally, the inventions that are patented differ greatly in their quality. The first two points may result in a selection bias, which may lead to an underestimation of our results. However, as Griliches suggests (1990, p. 1669), both problems can be taken care of by industry dummies, which are included in the regressions. Our results clearly show that there are significant differences in the number of patents across the included industries. Citing Frederic Scherer, Griliches (1990, p. 1669) suggests that for the third problem, i.e. that patents differ in their quality, one tries to invoke the help of the "law of large numbers", where the significance of any sampled patent can be interpreted as a random variable with some probability distribution. However, we think that our dataset, in particular the number of firm patents, not necessarily follows the law of large numbers. Finally, only the number of firm patents at the time of IPO is used.

Further research may also investigate this issue, analyzing how the innovation behavior of individual entrepreneurial firms is shaped by universities and regional endowment. This research should take the limitations of this study into account and use a more accurate dataset and measures for the quality of innovation behavior. Instead of simply measuring the number of patents, other measures like patent citations should be used. Finally, future research should also go a step further, analyzing the links—perhaps the role of the key inventor—across the entrepreneurial firms—and the university and/or the regions. In particular, future research should provide further evidence of crowding out effects of third party funding on entrepreneurial innovation behavior. In this context, the role of large incumbents should also be considered to analyze their impact in the triangle of university, regional competitiveness and entrepreneurial firms. By that, the role of regional government policy should also be mentioned and analyzed.

5 Summary and conclusions

It is widely observed that entrepreneurial activity varies across geographic space. Efforts to systematically link spatial variations in entrepreneurship with location specific characteristics showed that such spatial activity is not all random but rather shaped by factors associated with particular regions. While empirical evidence has already been provided supporting the impact of regions and universities on innovation activities, little is known about the separate and joint effect of those sources of spillovers. This paper has found that the innovation activity of young and high-tech firms is shaped by above-average local endowments and research intensive universities. While the results show that regional competitiveness and research output by universities are close substitutes in shaping firm behavior, it was possible to show that the existence of research intensive universities may have a stronger impact on firm behavior than regional competitiveness alone. While regional competitiveness is undoubtedly important in influencing the innovation behavior of young and small firms, the impact of the local endowment only significantly shapes the innovation behavior if research intensive universities are located in this region. As comparative advantage has become more important for regions, the results also show the significant impact that public policy has on the innovative process in young and high-tech firms. Public policy can shape the competitiveness of regions by providing both the infrastructure that enables young firms to absorb necessary resources as well as the right incentives for entrepreneurs and researchers.

However, there are also some puzzling results. A significant impact of third party funding on entrepreneurial innovation behavior was found. This can be explained by crowding out effects due to changes in the salary and bonus system of professors and researchers in Germany. While it might be interesting for researchers to invest in university-spinoffs and start their own firms, it is of less interest to cooperate with young and entrepreneurial firms. First, those entrepreneurial firms may directly compete with their own firm or research. The superior access to excellent researchers for professors leads to a comparative disadvantage for entrepreneurial firms. Secondly, research funding from the industry increases the personnel income of professors—directly in that they receive bonus-like payments and indirectly by increasing their bargaining power for their salaries. Although there is no empirical study about this effect, the phenomenon is actually a topic in the management press (see: Manager Magazine). Policy makers thus should place more attention on whether public founded research leads to spillover or crowding out effects for entrepreneurial firms. The results also suggest that regional governmental policy as expressed by different attitudes of parties toward an entrepreneurial society shapes the innovation behavior of entrepreneurial firms.

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