Location: A Neglected Determinant of Firm Growth

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Abstract: This paper links the performance of new technology firms, measured in terms of employment growth, to geographic location. We introduce a model of firm growth that is specific to characteristics of the location as well as the firm and industry. The model is estimated using a unique data set identifying the growth performance of small technology-based firms in Germany. We find that firm performance, as measured by employment growth, does appear to be influenced by locational characteristics as well as characteristics specific to the firm and the industry. In particular, the empirical evidence suggests that being located in an agglomeration rich in knowledge resources is more conducive to firm growth than being located in a region that is less endowed with knowledge resources. These results suggest the economic value of location as a conduit for accessing external knowledge resources, which in turn, manifests itself in higher rates of growth.
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1 Introduction

The last two decades have seen an explosion of interest in economic growth for a diversity of units of observation. While the Endogenous Growth Theory (Romer 1986, 1990; Lucas 1988) and New Economic Geography (Krugman 1991, 1998; Fujita et al. 1999) focus on growth at the macroeconomic level, a complementary literature has emerged examining the growth of cities (Glaeser et al. 1992; Henderson et al. 1995; Rosenthal and Strange 2003). One of the most important findings is that knowledge externalities, or what has become known as knowledge spillovers, provide a mechanism generating a superior economic performance, measured in terms of growth, in spatially concentrated areas rather than when economic activity is geographically dispersed. Both the endogenous growth literature as well as the studies on

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city growth suggest that agglomerations of economic activity have a positive impact on economic growth.

However, the actual mechanisms by which this growth takes place are less clear. An important step was made in penetrating the black box of urban space by Glaeser et al. (1992) and Feldman and Audretsch (1999), who demonstrated that not only is growth influenced by the spatial concentration of economic activity, but also the manner in which that activity is organized. In particular, they found that a diversity of complementary economic activity is more conducive to growth than specialization. Still, there is very little known about the impact of location on growth at the micro or firm level (Acs and Armington 2004: 270).

Does location make a difference in terms of firm growth? Are there systematic differences in growth rates of firms engaged in the same industry across geographic space? While the recent theories and empirical evidence about the linkages between agglomerations and growth at the spatial level would certainly imply that this relationship should also hold at the micro or firm level, in fact, very little is known about the locational impact on firm performance, as measured in terms of growth. This is because both the conceptual framework and empirical analyses have been aggregated to spatial units such as cities or industries located in cities, such that insights about the impact of location in general, and agglomerations in particular on firm growth have been limited.

It is important to note that this omission cannot be attributed to a lack of theories and empirical evidence about growth at the firm level in general: In fact, a large literature has been compiled providing both a conceptual framework as well as compelling evidence as to why performance, measured in terms of growth, varies systematically across firms (Sutton 1997; Caves 1998). While the literature on Gibrat's Law and industry dynamics has produced stylized facts about the roles that characteristics specific to the firm, such as size and age, and industry, such as high tech versus low tech, play in shaping growth, locational aspects have been overlooked in these studies.

This paper is a modest attempt to reduce these gaps in the literatures on spatial growth on the one hand and firm growth on the other, by explicitly linking the performance of new technology firms, measured in terms of growth, to the geographic location. To do this, we will combine the conceptual frameworks developed in these two distinct literatures to introduce a model of growth that is specific to characteristics of the location as well as the firm and industry. The model will be estimated using a new data set identifying the growth performance of small technology-based firms.

The paper is organized as follows: The next section deals with the determinants of firm growth, discusses why location might be an important (but overlooked) driver of firm growth and presents the two fundamental hypotheses to be tested in this paper. Section 3 provides the econometric model, introduces the data set and discusses the variables used in the estimations. Section 4 presents the results of the econometric analysis. Section 5 concludes.

2 Determinants of Firm Growth—Why Should Location Matter?

In response to a literature that focused on static relationships, Mansfield (1962: 1023) made a plea some 40 years ago for a greater emphasis on understanding the dynamic performance of industries that underlies the process of economic growth: "Because there have been so few econometric studies on the birth, growth, and death of firms, we lack even crude answers to the following basic questions regarding the dynamic processes governing an industry's structure: What are the quantitative effects of various factors on the rates of entry and exit? What have been the effects on a firm's growth rate?" Scholars responded to Mansfield's plea by undertaking a wave of studies to uncover the various dimensions of industry dynamics. The resulting literature on industry evolution examined the process by which new firms enter an industry, either survive or exit, and ultimately grow. This literature has become so thorough and compelling that it required two recent articles in the *Journal of Economic Literature* (Sutton 1997 and Caves 1998) to summarize what has been learned about the entry, growth, survival, and mobility of firms.

The starting point for much of the empirical work in this area is a relationship known as "Gibrat's law". In his exhaustive survey in the *Journal of Economic Literature*, Sutton (1997: 43) interpreted Gibrat's law not as a prima facie law but rather pragmatically as an assumption by which "the probability that the next opportunity is taken up by any particular active firm is proportional to the current size of the firm." From this simple proposition follows the equally simple prediction of proportional effect, that growth rates should be independent of size, which Mansfield (1962: 1030–1031) characterized as "the probability of a given proportionate change in size during a specified period is the same for all firms in a given industry, regardless of their size at the beginning of the period."

A wave of empirical studies has tested the validity of Gibrat's law (Sutton 1997; Caves 1998). The earlier studies seemed to provide empirical evidence supporting the law in that firm growth was independent of size. However, these studies were generally based on samples of large corporations. When subsequent studies included a broader range of firm size, Gibrat's law was found not to hold. In fact, when small firms were included in the sample, firm growth was found to be negatively related to size. In addition, younger firms are found to grow at a higher rate than their more mature counterparts.

Resolution to this paradox was provided by Jovanovic (1982), who introduced a model in which new entrants, which he terms entrepreneurs, face costs that are not only random but also differ across firms. A central feature of his model is that a new firm does not know with certainty what its cost function, or relative efficiency is, but rather discovers this through a process of learning from the actual post-entry performance. The new firm will typically have a small start-up size. Those firms that learn the most will enjoy the greatest growth. Pakes and Ericson (1998) include active learning into the model and show that entrants that are able to actively learn, through R&D activities, will experience greater growth rates. Thus, the models by Jovanovic (1982) and Pakes and Ericson (1998) suggest that firm growth tends to be systematically higher in smaller firms that are able to learn.

Interest in industry dynamics also spread to regional economics. A large literature has developed examining the determinants of entry across geographic space (Carlton 1983; Bartik 1989; Acs and Armington 2004). Similarly, a series of studies have identified the impact that entry rates have on subsequent regional or city growth (Fritsch 1997). While studies in regional economics have identified the determinants and impact of new-firm entry, no analogous studies have been undertaken about the role that location plays in the subsequent post-entry performance. Several scholars have realized this and emphasize that there is urgent need for studying whether the economic and human capital characteristics of regions influence the growth and survival of young firms (Acs and Armington 2004: 270).

The reason for this omission may be both conceptual and empirical. At the conceptual level, there have not been models linking the post-entry performance of individual firms to regional growth. At the empirical level, linking entry to growth was feasible for data sets aggregated to geographic units of observation, such as cities or regions. However, analyzing the post-entry performance of firms in a spatial context requires longitudinal data at the establishment or enterprise level.

Despite the omission of locational aspects from studies focusing on firm growth, there are a number of reasons to expect that location should play an important role in shaping the growth of enterprises. Theories dating back to at least Marshall (1890) suggest that location within a geographically concentrated area, or an agglomeration, results in greater firm efficiencies. The first type of benefit accrues from labor market pooling. The second type is the provision of non-traded inputs, or the development of specialized intermediate goods. The third source emanates from knowledge externalities or knowledge spillovers. As Glaeser et al. (1992: 1127) point out, knowledge spills over within a geographically bounded space because, "After all, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents." That is, location and proximity matter. While the costs of transmitting information may be invariant to distance, the cost of transmitting knowledge rises with distance.[1]

Undoubtedly among these three forces which are hypothesized by Marshall to increase firm growth in agglomerations, localized knowledge externalities have gained the most prominence in the empirical literature (see Feldman 1999 for a survey). The most influential of these studies have been based on the knowledge production function. As introduced by Griliches (1979), the knowledge production function links inputs in the innovation process to innovative outputs. Griliches pointed out that the most decisive innovative input is new economic knowledge, and the greatest source that generates new economic knowledge is generally considered to be R&D. Jaffe (1989), Jaffe et al. (1993), and Audretsch and Feldman (1996) provided empirical evidence supporting the theory that knowledge spills over spatially bounded regions.

The results of this literature identifying the propensity for knowledge inputs and spillovers to cluster geographically would suggest that firms using knowledge inputs will exhibit a superior performance if they are located in an agglomeration. A firm located within an agglomeration will

[1] New knowledge is often unstructured and highly complex and can thus best be transferred "face to face" (Polanyi 1958). Furthermore, new knowledge is often produced cooperatively in joint ventures or innovation networks. In these cases the advantage of spatial proximity is not so much the reduction of information costs but the fact that only close personal relationships allow for the evolution of incentive and sanction mechanisms necessary for the keeping of the implicit cooperation contracts (Bröcker 1995).

have superior access to both knowledge resources as well as knowledge spillovers. This leads us to the two *fundamental hypotheses* of this proposal:

1. *The performance of a high-technology firm should be superior if the firm is located within an agglomeration containing knowledge sources complementary to its economic activity.* This would suggest that the growth performance of technology firms should be systematically related to locational characteristics.
2. *The impact of location on firm growth should be greater in industries that are more knowledge intensive.* Industries where knowledge is not an important factor of production depend less on knowledge inputs and provide less of a potential for knowledge spillovers and for learning from others.

3 The Empirical Approach

3.1 The Econometric Model

To identify the locational impact on firm growth, we propose a model linking firm growth to characteristics specific to the *firm*, *industry*, and *location*.

Our starting point is the most prevalent model for identifying the determinants of growth at the level of the firm, which has been used to test Gibrat's law. As mentioned before, Gibrat's law is a proposition stating that the probability of a given proportionate change in firm size during a specified period is the same for all firms in a given industry—regardless of their initial size. This means that, according to Gibrat's law, firm growth is regarded as a purely stochastic phenomenon resulting from the chance operation of a large number of forces acting independently of each other. The economic motivation behind this may be expressed as follows: "The chances of growth or shrinkage of individual firms will depend on their profitability as well as on many other factors which in turn depend on the quality of the firm's management, the range of its products, availability of particular inputs, the general economic environment, etc. During any particular period of time, some of these factors would tend to increase the size of the firm, others would tend to cause a decline, but their combined effect would yield a probability distribution of the rates of growth (or decline) for firms of each given size. It is commonly asserted that this probability distribution is the same for all size-classes of firms." (Singh and Whittington 1975: 16).

Formalizing the relationship between size and growth, Gibrat's law implies that the present size of firm i in period t may be decomposed into the product of firm size in some previous period $t-1$ and a "proportional effect" as represented in equation (1):

$$SIZE_{i,t} = (1 + \varepsilon_{i,t})SIZE_{i,t-1} \,. \tag{1}$$

In (1) the term $(1 + \varepsilon_{i,t})$ denotes the proportional effect for firm i in period t and $\varepsilon_{i,t}$ is a random shock which is assumed to be identically and independently distributed with mean μ_ε and variance σ_ε^2. Following the process in (1) to its origin we may as well write:

$$SIZE_{i,t} = SIZE_{i,0}(1 + \varepsilon_{i,1})(1 + \varepsilon_{i,2})...(1 + \varepsilon_{i,t}) \,. \tag{2}$$

Taking the natural log and making use of the fact that for small ε, $\ln(1 + \varepsilon) \approx \varepsilon$ yields:

$$\ln(SIZE_{i,t}) = \ln(SIZE_{i,0}) + \sum_{k=1}^{t} \varepsilon_{ik} \,. \tag{3}$$

As we have assumed the increments $\varepsilon_{i,t}$ to be independent variates with mean μ_ε and variance σ_ε^2, we have that as $t \to \infty$, so the term $\ln(SIZE_{i,0})$ will be small compared to $\ln(SIZE_{i,t})$, that the distribution of $\ln(SIZE_{i,t})$ is approximated by a normal distribution with mean $\mu_\varepsilon t$ and variance $\sigma_\varepsilon^2 t$.[2] In other words: The limiting distribution of $SIZE_{i,t}$ is lognormal.[3]

Firm growth can then be expressed as the difference in the log of firm size (i.e., the number of employees) between the current period t and some previous period $(t-1)$:

$$GROWTH_{it} = \ln(SIZE_{i,t}) - \ln(SIZE_{i,t-1}) \,. \tag{4}$$

A simple way to examine the relationship between firm growth and size in a regression framework is to estimate an equation of the following form:

$$GROWTH_{i,t} = B_0 + B_1 \ln(SIZE_{i,t-1}) + \varepsilon_{i,t} \,, \tag{5}$$

where B_1 represents the effect of initial size on the subsequent rate of a firm's growth. If $B_1 = 0$ then firm growth is independent of initial firm size and the central tenet of Gibrat's law of proportionate effect holds.[4] If $B_1 < 0$ this

[2] Derived by applying the "Central Limit Theorem".
[3] Almus and Nerlinger (2000) confirm this distributional assumption via kernal density estimates for German firms 1990–1996.
[4] Tschoegel (1983) argues that robust acceptance of Gibrat's law also requires that growth does not persist from one period to the next and that the variability of growth is independent of firm size.

implies that small firms on average grow faster than their larger counterparts, whereas when $B_1 > 0$ then large firms tend to grow faster than smaller firms.

There are, however, good reasons to assume that firm growth is more than just a purely stochastic phenomenon and that there are other factors—apart from firm size—that may have a systematic influence on the growth performance of firms. Based on the seminal papers by Hall (1987) and Evans (1987) the empirical growth equation for testing the counter-hypothesis that characteristics specific to the individual firm such as size and age impact firm growth can be specified as:

$$GROWTH_{i,t} = B_0 + B_1 \ln(SIZE_{i,t-1}) + B_2 \ln(SIZE_{i,t-1})^2 + B_3 \ln(AGE_{i,t-1}) + \varepsilon_{i,t} , \qquad (6)$$

where growth for firm i in period t is a function of initial firm size, size^2, age, and a stochastic error term $\varepsilon_{i,t}$. Sutton (1997) and Caves (1998) survey and report on the large number of empirical studies estimating (6). The evidence is systematic and compelling that both size and age are negatively related to firm growth.

Note that (6) only considers characteristics specific to the firm. In this paper, we extend the classical firm-specific approach by considering industry-specific and location-specific determinants of growth as well. In particular, we will include the types of location-specific measures used by Carlton (1983), Bartik (1989), and Reynolds et al. (1994). The location-specific variables will include measures reflecting the importance of knowledge and technology at that location. Our econometric model (basic version) has the form

$$GROWTH_{i,t} = B_0 + B_1 \ln(SIZE_{i,t-1}) + B_2 \ln(SIZE_{i,t-1})^2 + B_3 \ln(AGE_{i,t-1}) + B_4 D_{ind} + B_5 KNOWLEDGE_{r,t-1} + B_6 X_{r,t-1} + \varepsilon_{i,t} , \qquad (7)$$

where D_{ind} is a vector of industry dummies controlling, for example, for the knowledge intensity of production in a specific sector. $KNOWLEDGE_{r,t-1}$ is a region-specific knowledge or agglomeration variable and $X_{r,t-1}$ is a vector of other region specific variables hypothesized to have an impact on firm growth.

While the existing literature on firm growth, as represented by (6), has implicitly assumed that location plays no role in shaping growth, (7) reflects the major hypothesis of this paper whereby firm performance is enhanced in locations providing greater access to knowledge resources.[5] If the assumption that location plays no role is true, then the coefficients of the variables reflecting location-specific characteristics will be equal to zero. However, if the hypotheses posed here are correct, and firm growth is influenced by locational factors, then the coefficients will not be equal to zero. In particular, if knowledge externalities improve firm performance, then the coefficients will be greater than zero.

In a nutshell, positive coefficients on measures of knowledge factors and the degree of agglomeration would suggest that firm growth is systematically and positively shaped by being located in regions rich in knowledge.

3.2 Data and Measurement

There are many indications from the empirical literature that knowledge activities tend to benefit more from agglomeration than do non-knowledge activities, at least in manufacturing (Audretsch and Feldman 1996; Zucker et al. 1998; Maurel and Sédillot 1999). Therefore, a data set consisting of young knowledge intensive (technology) firms appears to be particularly well-suited to examine the impact of location on firm performance. By examining the records from the Initial Public Offering (IPO) of 212 knowledge-based firms that were publicly listed on the "Neuer Markt" (New Market) in Germany between 1997 and 2002, we created such a data set.[6] Only firms with their headquarters in Germany were considered. Most of the relevant data were publicly available from online data sources such as Deutsche Boerse AG (2003), Onvista AG (2003) or SdK e.V. (2003). However, for a number of (particularly smaller) firms there were no employment data available online. In these cases we performed a supplementary e-mail survey to complete the data base.

[5] Our hypothesis is, in other words, that knowledge-rich locations provide a particularly fertile soil for the growth of young, technology-oriented firms.

[6] The "Neuer Markt", launched in 1997 by Deutsche Boerse, the German stock exchange, has been Europe's most important growth stock market and Europe's closest equivalent to the Nasdaq. In conjunction with the fundamental restructuring of Deutsche Boerse AG the "Neuer Markt" has been closed in June 2003. The restructuring had no impact on the tradability of stocks formerly listed on the "Neuer Markt" (Deutsche Boerse AG 2002: 3). The firms still exist—and most of them continue to grow—although they are no longer bundled in a single index. They are now listed on the newly created indices TECDAX (for Blue Chips), Technology All Share Index and SDAX (a small cap index not restricted to technology firms).

Total employment with the firms included in the data set increased from 26,845 employees in 1997 to 104,917 employees in 2002, which illustrates that the mean employment growth of the firms included in our sample was very high (Table 1). Also reflected in Table 1 is the fact that firm growth rates were highly specific to the particular sector. However, the question addressed in this paper is not why the growth of these high-technology enterprises is so high,[7] but, rather, whether the growth performance of these firms is shaped by location.

Table 1: *Employment Growth Rates, Employees and Number of Firms by Sector*

	Compound annual growth rate (percent)		Number of employees	Number of firms
	1998–2002	2000–2002	September 2002	September 2002
Biotech	46.5	17.2	3,005	14
Media&Entertainment	42.2	−12.4	4,560	26
Internet	40.7	−4.0	14,364	31
IT Services	31.2	8.3	15,297	26
Financial Services	29.4	−9.5	2,231	2
Telecommunications	29.0	−1.3	10,465	12
Technology	26.2	11.8	23,354	47
Medtech&Health	24.0	21.1	1,804	9
Industrials&Industrial Services	21.3	10.4	18,801	13
Software	17.5	−2.6	11,036	32
All sectors	27.6	3.9	104,917	212

Source: Deutsche Boerse AG (2003), Onvista AG (2003), SdK e.v. (2003), own survey.

The geographical breakdown used in our analysis is planning regions. The whole of Germany consists of 97 such planning regions ("Raumordnungs-" or "Analyseregionen") intended to be comparable regions "that reflect in acceptable approximation the spatial and functional interrelation between core cities and their hinterland." (BBR 2001: 2). For the purpose of our investigation planning regions are better suited than "Kreise"[8] as they are more homogeneous and as they are large enough

[7] Klodt (2001) and Klodt et al. (2003) provide an excellent discussion of possible reasons for such an accelerated growth.
[8] "Kreise" are smaller units than planning regions. There are 440 "Kreise" in Germany. See BBR (2001) for more information about spatial planning and the different regional units in Germany.

to assume that spillovers are primarily intraregional in nature. It is noteworthy that the geographical spread of "Neuer Markt" firms and "Neuer Markt" employment is very uneven: In 2002, while several planning regions hosted no "Neuer Markt" firms at all, the leading region (Munich) had more than 20,000 employees in "Neuer Markt" firms (see Figure A1 in the Appendix for illustration).

In order to empirically test for the impact of location on the growth performance of knowledge-intensive firms, variables reflecting knowledge characteristics specific either to the industry or the location need to be added to the basic model linking firm characteristics to growth as discussed in Section 3.1. Therefore, in addition to the usual measures of firm age[9] and firm size (employment in 1997), industry- and region-specific measures are included in the estimations (see Tables 2 and 3 for some descriptive statistics).[10]

Table 2: *Descriptive Statistics* [a]

	Mean	Std.Dev.	Minimum	Maximum
GROWTH	1.433820	0.923475	−.699456	4.90528
AGE	1.712890	1.343200	−.693147	4.67282
SIZE	4.166830	1.421420	0.000000	7.12528
SIZESQRD	19.373400	11.499000	0.000000	50.76970
KIS	0.349057	0.477800	0.000000	1.00000
EAST	0.113208	0.317596	0.000000	1.00000
VC	0.844340	0.363391	0.000000	1.00000
HC	0.674528	0.469660	0.000000	1.00000
NME	8.242160	1.444320	3.713570	9.96801
INDENS	−2.379230	0.299320	−3.248500	−1.71679
POPDENS	6.313300	0.869304	4.669030	8.24280
STUPINT	0.316070	0.130215	0.105152	0.68400

[a] All independent variables except for the dummies in logarithms. 212 cases (firms in the sample).

Source: BBR (2001), BVK e.V. (2003), Deutsche Boerse AG (2003), Onvista AG (2003), SdK e.v. (2003), ZEW (2003), own survey.

[9] The average firm age in 1997 was 10.5 years. 40 percent of firms in the sample were younger than 5 years and more than 60 percent were younger than 10 years. Only 13 percent were older than 20 years.

[10] Note that, as we investigate firm growth in the period 1997–2002, our year "$t-1$" is 1997.

Table 3: *Correlation Matrix*

	1	2	3	4	5	6	7	8	9	10	11	12
GROWTH	1.00											
AGE	−0.44	1.00										
SIZE	−0.67	0.47	1.00									
SIZESQRD	−0.59	0.44	0.97	1.00								
KIS	0.06	0.13	0.10	0.12	1.00							
EAST	−0.11	−0.01	0.09	0.08	−0.07	1.00						
VC	0.01	−0.02	−0.02	−0.01	−0.15	0.07	1.00					
HC	0.16	−0.15	−0.12	−0.11	−0.17	0.25	0.37	1.00				
NME	0.10	0.02	0.00	0.03	−0.15	−0.08	0.51	0.66	1.00			
INDDENS	0.00	0.04	0.01	−0.01	0.12	−0.67	−0.33	−0.25	−0.10	1.00		
POPDENS	0.05	−0.08	−0.07	−0.05	−0.26	0.27	0.36	0.45	0.35	−0.43	1.00	
STUPINT	0.03	0.02	−0.05	−0.06	0.01	−0.27	0.00	0.02	0.32	0.38	−0.29	1.00

Source: Same as for Table 2. Own calculations.

We use an *industry-specific* dummy variable *KIS* (short for knowledge intensive sector), which takes a value of 1 if the firm belongs to an industry with an above average share of knowledge workers in its labor force and a value of 0 otherwise. The share of knowledge workers in an industry's labor force is proxied by the share of academics or, alternatively, by the share of scientists and technicians (see Table A1 in the Appendix for details). Sectors with an above-average share of knowledge workers according to these definitions are highlighted in Table A1.

The rationale for using this measure of knowledge intensity (apart from data availability) is threefold: First of all, a high share of knowledge workers in the labor force indicates a high dependence of the firms' production process on knowledge—be it produced internally (within the firm) or externally. Second, the higher the share of highly qualified knowledge workers the higher is ceteris paribus the firms' ability to absorb knowledge produced elsewhere. And third, a particularly high share of permanently employed knowledge workers may be interpreted as an investment in active learning, which is seen as a key determinant of firm growth and profitability in the literature (Pakes and Ericson 1998; Dosi et al. 1995; Ballot and Taymaz 1997).[11]

We use two *region-specific* measures reflecting the knowledge resources and other spillover sources of the region, including a dummy variable for

[11] Although this interpretation is straightforward it should be noted that it only holds ceteris paribus as other factors might have an impact on the share of knowledge workers as well.

regions with a highly qualified labor force share in the highest 20 percent (*HC* = human capital)[12], and the amount of employment in the region accounted for by "Neuer Markt" firms (*NME* = "Neuer Markt" employment). The reason we use two distinct measures of agglomeration is that human capital is a relatively broad measure for the stock of knowledge capital in a region, as it is aggregated over all sectors. "Neuer Markt" employment, by contrast, is narrower as it is restricted to what may be called the "new economy" sector of the economy. Thus, the distinction between the two is in a way similar to the distinction between the broader concept of urbanization economies and the narrower concept of localization economies, introduced by Hoover (1937).

It should be noted that it is beyond the scope of this paper to empirically discriminate between knowledge spillovers and the pooling of highly-skilled labor as determinants of firm growth. The central question of this paper is a more basic one: Does the availability of localized knowledge resources impact firm growth or not?

Following Rauch (1993) one may interpret the average level of human capital in a region as a local public good entering the resident firms' production function. This interpretation is straightforward but rather abstract as it leaves open the exact description of the mechanism by which human capital contributes to higher growth. Such a mechanism is provided by Jovanovic and Rob (1989). In their model, individual agents (e.g., entrepreneurs) augment their knowledge through pairwise meetings with a finite number of randomly chosen other agents. The higher the average level of human capital, the higher is the likelihood that these meetings prove successful and the more rapid will be the diffusion and growth of knowledge.[13] Acs and Armington, in the same vein, argue that "higher education trains individuals to rationally assess information, and to seek new ideas. Therefore more educated people are more likely to acquire useful local knowledge spillovers from others who are involved in reseach or in managing some service business." (Acs and Armington 2004: 256). One might add that more educated people are also more likely to produce knowledge—part

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[12] Regionally disaggregated data on highly qualified employees are available from the German Federal Office for Building and Regional Planning (BBR). Highly qualified employees are—according to the definition used by the BBR—employees who hold a university degree, a degree by a technical college (Fachhochschule) or who have graduated from a higher vocational school (Höhere Fachschule).

[13] See Bröcker (2004) for a theoretical treatment of the interrelation between agglomeration and knowledge diffusion.

of which is locally bound for the reasons discussed in footnote 1—that proves to be useful to others. Therefore, we have good reason to expect that firms in agglomerations rich in human capital have access to superior knowledge which increases their profitability (and accelerates their growth) relative to competitors in regions less well endowed with human capital.

The interpretation of the variable "Neuer Markt" employment *(NME)* in the region is analogous to the interpretation of the variable human capital *(HC)*, with the slight difference that "Neuer Markt" employees represent a rather specific form of human capital and therefore provide a somewhat different local public good. One may also argue that a high number of Neuer Markt employees in a region makes knowledge spillovers between them more likely.

Apart from these variables measuring region-specific knowledge resources we employ several region-specific control variables. Included in the basic model version is a dummy variable *VC* for the presence of venture capital firms in the region, taking into account that new ideas are most likely to occur and to be put in practice "where knowledge workers ... hook up with venture capitalists—the suppliers not only of money but of management expertise of the kind most technology-based start-ups lack" (Norton 2000, ch. 3). Further included is a dummy variable *EAST* for firms with a location in one of the five new eastern states (the former East Germany). The latter variable is considered because the structure of the East German economy still differs substantially from the structure of the West German economy.

In an extended model version we control for the impact of agglomeration in general (without special reference to knowledge resources) by including variables measuring population density (*POPDENS*) and industry density (*INDDENS*). Finally, we include the high-technology start-up rate of the region (*STUPINT*) as a measure of the region's entrepreneurial dynamics in the technologically most advanced industries .[14]

As can be seen from Table 3, the correlation between the explanatory variables is relatively low, such that multicollinearity issues should not cause major problems in the regressions.

[14] The exact definition of *POPDENS*, *INDDENS* and *STUPINT* is given in Section 4.3.

4 Results

4.1 Growth Conditional on Survival

Table 4 shows the results of estimating the impact of location on firm growth,[15] 1997–2002, for the publicly listed German firms. To estimate the

Table 4: *Regression Models Estimating Firm Growth and Survival*

Dependent Variable	Agglomeration variable: *HC*			Agglomeration variable: *NME*		
	Model (1) OLS *GROWTH*	Model (2) Heckit *GROWTH*	Model (3) Probit *SURVIVAL*	Model (4) OLS *GROWTH*	Model (5) Heckit *GROWTH*	Model (6) Probit *SURVIVAL*
Constant	4.206*** (0.339)	3.950*** (0.466)	0.557 (0.494)	3.770*** (0.410)	3.325*** (0.585)	0.557 (0.494)
AGE	−0.086** (0.037)	−0.086** (0.039)	0.016 (0.096)	−0.097*** (0.037)	−0.097** (0.042)	0.016 (0.096)
SIZE	−1.049*** (0.155)	−1.019*** (0.139)	0.143* (0.087)	−1.030*** (0.158)	−0.980*** (0.143)	0.143* (0.087)
SIZESQRD	0.083*** (0.017)	0.082*** (0.016)	–	0.080*** (0.018)	0.078*** (0.016)	–
KIS	0.230** (0.089)	0.300** (0.138)	–	0.234*** (0.089)	0.344** (0.146)	–
EAST	−0.205* (0.121)	−0.192 (0.140)	–	−0.091 (0.111)	−0.064 (0.140)	–
VC	−0.081 (0.103)	−0.064 (0.128)	–	−0.134 (0.113)	−0.121 (0.137)	–
HC	0.218*** (0.084)	0.222** (0.102)	–	–	–	–
NME	–	–	–	0.075** (0.033)	0.082** (0.036)	–
LAMBDA	–	0.485 (0.699)	–	–	0.741 (0.744)	–
OTNMF	–	–	0.446 (0.367)	–	–	0.446 (0.367)
IISMS	–	–	−0.610** (0.238)	–	–	−0.610** (0.238)
	$R^2 = 0.561$ Adj. $R^2 = 0.546$ F[7,204] = 37.25	$R^2 = 0.562^a$ Adj. $R^2 = 0.545$ F[8,203] = 32.58	McFadden: 0.072 Veall/Zim: 0.1205	$R^2 = 0.561$ Adj. $R^2 = 0.546$ F[7,204] = 37.26	$R^2 = 0.563^a$ Adj. $R^2 = 0.546$ F[8,203] = 32.76	McFadden: 0.072 Veall/Zim: 0.1205
	N = 212	N = 212	N = 243	N = 212	N = 212	N = 243

Note: Standard errors, robust to heteroskedasticity, are reported in parentheses. ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively.
[a] Not using OLS. R^2 is not bound in [0,1].

Source: Same as for Table 2. Own calculations.

[15] Remember from equation (4) that growth is measured as $\ln(SIZE)_t - \ln(SIZE)_{t-1}$. We set $t = 2002$ and $t - 1 = 1997$.

growth equation, the natural logs of each independent variable is used, other than for the dummy variables.

In a first step we estimated firm growth using OLS estimation (see models (1) and (4) in Table 4). Concerning the impact of the firm-specific variables (*SIZE* and *AGE*) the estimation of models (1) and (4) yielded standard results: The negative coefficient for firm age is consistent with the so-called "stylized finding" that firm growth tends to decline as the firm evolves over its life cycle. While the negative and statistically significant coefficient of firm size indicates that growth tends to decline with firm size, the positive coefficient of the squared term (*SIZESQRD*) suggests that growth tends to decrease more slowly as the firms become larger.[16]

Most important in the context of our investigation is the impact of the variables representing regional knowledge resources. The positive and highly significant coefficient of human capital *(HC)* in the region suggests that firms experience higher growth rates in agglomerations characterized by a high density of highly qualified employees (model 1). The same result emerges when the alternative measure, the log of "Neuer Markt" employment (*NME*) in the region, is used (model (4)). Thus, both measures indicate that firm growth is positively influenced by being located in an agglomeration rich in knowledge resources.

As concerns the region-specific control variables, there is no evidence that the presence of venture capital firms in the region (*VC*) influences the growth rates. The East Germany dummy (*EAST*) has a negative sign and is weakly significant (at the 10 percent level) in model (1), but is insignificant in all other model specifications.

However, as the positive and statistically significant coefficients suggest, firm growth is positively influenced by the knowledge intensity of the sector (*KIS*), which we think is another remarkable result. A possible interpretation of this result—which is in line with theoretical models such as Ericson and Pakes (1995), Dosi et al. (1995) or Ballot and Taymaz (1997)—is that young firms that have *invested in active learning* by employing (on average) a particularly high proportion of knowledge workers in their labor force experience faster growth.

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16 The above estimates of the growth model implicitly assume that firm size is exogenous and growth is endogenous. To challenge this assumption of exogeneity, a Hausman test for the endogeneity of the size variable was undertaken. Following the method proposed by Durbin, the rank of the size variable was used as an instrument. The result of the Hausman test gave no hint on endogeneity of the size variable.

4.2 Unconditional Growth

In models (1) and (4) we have only considered the 212 "Neuer Markt" firms that survived until September 2002, i.e., we have analyzed *growth conditional on survival*. However, an important qualification is that various "Neuer Markt" firms closed or went bankrupt in the period under consideration (1997–2002). This neglect of exit might lead to a sample selection bias in our results.

We have therefore re-calculated our basic regressions using the two-stage Heckit (after Heckman 1976) procedure. This procedure consists of two steps: (i) a probit estimate of survival from the whole sample (including the 212 survivors plus 31 further firms that closed or went bankrupt before September 2002) and (ii) an estimate of growth from the selected sample of "survivors" using the estimated expected error (the inverse mills ratio *LAMBDA*) obtained from step 1 as a correction factor (see Wooldridge 2002: 564 for details).

We follow Evans (1987) by using firm age and size as arguments in the survival function. Additional identifying variables are a dummy for the availability of other "Neuer Markt" firms in the region (*OTNMF*) and a sector dummy for Internet, IT Services, Media and Software firms (*IISMS*) which are hypothesized to have a higher likelihood of failure than firms belonging to other sectors.

As can be seen from Table 4, the most important variable in explaining survival[17] (or exit, respectively) is the sector dummy for Internet, IT Services, Media and Software firms (IISMS), which has a negative sign and is significant at the 5 percent level. This partly reflects the "death of the dot.coms" phenomenon that could be observed in 2000 and 2001. Size has a positive impact on the probability of survival and is weakly significant (at the 10 percent level). All other variables have no significant impact on survival.[18]

Moreover—and most important in the context of our investigation—the results of the Heckit estimation of firm growth (models (2) and (5) in Table 4) reveal that the inverse mills ratio term (*LAMBDA*) is statistically insignificant in both cases and that the differences between the OLS and Heckit estimates are practically small. Thus, our basic results on the impact

[17] The variable *SURVIVAL* takes a value of 1 if firm *i* has survived until September 2002 and a value of 0 if that firm hasn't survived.
[18] Note that models (3) and (6) in Table 4 are identical since the different agglomeration variables do not enter the survival function.

of agglomeration ("knowledge clustering") on firm growth presented in Section 4.1 do not only apply to "growth conditional on survival" but still hold after we have controlled for sample selection bias.

4.3 Is It Density or Entrepreneurial Dynamics Rather Than Knowledge Resources?

One might argue that the strong results obtained for the regional knowledge variables *HC* and *NME* in Sections 4.1 and 4.2 just reflect the general advantages of a high density of economic activities, i.e., one might suspect that agglomeration in general and not the agglomeration of knowledge resources runs the story. In that case the positive and significant variables *HC* and *NME* would just reflect the impact of left out agglomeration variables without particular relation to knowledge.

Moreover, there is an emerging literature linking entrepreneurship to regional growth, i.e., it is hypothesized that a vivid entrepreneurial environment (usually measured in terms of start-up intensity) accelerates regional growth (see, for example, Audretsch and Keilbach (2004) or Fritsch and Müller (2005)). Clearly, if this holds at the regional (macro) level it should also be observable at the micro or firm level.

We have therefore extended the models used in Sections 4.1 and 4.2 to include additional explanatory variables measuring agglomeration in general as well as regional entrepreneurial dynamics. The variable *POPDENS* measures population density (inhabitants per square kilometer) in the German planning regions in 1997,[19] whereas *INDDENS* (= industry density) relates a region's manufacturing employment to the number of inhabitants in 1997.[20] Entreprenuerial dynamics is measured by the regions high-tech start-up rate (*STUPINT*).[21]

As can be seen from Table 5 neither the density variables nor the high-tech start-up rate have a significant influence on firm growth. Moreover, a comparison of Tables 4 and 5 reveals that the results derived in Sections 4.1 and 4.2 change only marginally when including additional explanatory variables.

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[19] The data source is Statistisches Bundesamt (1999).
[20] The data are taken from Statistische Ämter des Bundes und der Länder (2005).
[21] Start-up intensity (*STUPINT*) is defined as regional high-tech start-ups per 10,000 employed persons. The data source is ZEW Mannheim (2003).

Table 5: *The Impact of Additional Explanatory Variables*

	Agglomeration variable: *HC*		Agglomeration variable: *NME*	
Dependent Variable	Model (7) OLS *GROWTH*	Model (8) Heckit *GROWTH*	Model (9) OLS *GROWTH*	Model (10) Heckit *GROWTH*
Constant	3.934***	3.671***	3.969***	3.256***
	(0.646)	(0.782)	(0.507)	(0.798)
AGE	−0.086**	−0.086**	−0.097***	−0.097**
	(0.037)	(0.038)	(0.037)	(0.041)
SIZE	−1.044***	−1.016***	−1.017***	−0.974***
	(0.155)	(0.140)	(0.156)	(0.142)
SIZESQRD	0.083***	0.082***	0.078***	0.076***
	(0.017)	(0.016)	(0.017)	(0.016)
KIS	0.227**	0.295**	0.233**	0.333**
	(0.090)	(0.141)	(0.092)	(0.146)
EAST	−0.299*	−0.280	−0.147	−0.127
	(0.166)	(0.191)	(0.138)	(0.191)
VC	−0.111	−0.096	−0.167	−0.150
	(0.115)	(0.139)	(0.121)	(0.145)
HC	0.231**	0.230**	–	–
	(0.091)	(0.108)		
NME	–	–	0.087**	0.093**
			(0.037)	(0.040)
INDDENS	−0.164	−0.157	−0.953	−0.084
	(0.207)	(0.220)	(2.026)	(0.221)
POPDENS	−0.017	−0.012	−0.017	−0.015
	(0.055)	(0.063)	(0.057)	(0.063)
STUPINT	0.004	0.043	−0.265	−0.230
	(0.333)	(0.370)	(0.369)	(0.406)
LAMBDA	–	0.455	–	0.679
		(0.708)		(0.737)
	$R^2 = 0.562$	$R^2 = 0.563$[a]	$R^2 = 0.563$	$R^2 = 0.565$[a]
	Adj. $R^2 = 0.541$	Adj. $R^2 = 0539$	Adj. $R^2 = 0.541$	Adj. $R^2 = 0.541$
	F[10,201] = 25.82	F[11,200] = 23.44	F[10,201] = 25.88	F[11,200] = 23.59
	N = 212	N = 212	N = 212	N = 212

Note: Standard errors, robust to heteroskedasticity, are reported in parentheses. ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively. The probit estimation of survival is the same as in Table 4.
[a] Not using OLS. R^2 is not bound in [0,1].

Source: Same as for Table 2. Own calculations.

In addition, various other sensitivity analyses were performed.[22] We have, for example, run regressions in which the knowledge-related variables

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[22] Results are available from the authors upon request.

HC and *NME* were not complemented (as in Table 5) but replaced[23] by *POPDENS*, *INDDENS*, and *STUPINT*. Dropping the regional knowledge variables clearly worsened the fit of the model and resulted (again) in insignificant coefficients of the general (non knowledge-related) density and entrepreneurship variables.

In sum, it appears that our results on the importance of regional knowledge resources derived in Sections 4.1 and 4.2 are very robust to changes in the model specification.

4.4 High-Knowledge versus Low-Knowledge Sectors

Since the availability and the spillover of knowledge are presumably less important in sectors where knowledge does not play an important role, in Table 6 firms in the high knowledge-intensive sectors are separated from low-knowledge sectors.[24] "High-knowledge" is defined as the subsample of firms belonging to sectors with an above-average employment share of academics.

As may be seen from Table A1 in the Appendix, these high-knowledge sectors are Biotech, Software, Internet, Industrials&Industrial Services and IT Services.[25] Accordingly, sectors with a below-average employment share of academics are labelled "low-knowledge" sectors.[26]

As the positive and statistically significant coefficients of regional human capital (*HC*) indicate, the growth of knowledge intensive firms is higher in regions with a high agglomeration of knowledge assets (models (11) and (12) in Table 6). The same holds when we use "Neuer Markt" employment (*NME*) as agglomeration variable, as can be seen from Table A2 in the Appendix.

However, this does not appear to be the case in the low-knowledge sectors (see models (14) and (15) in Table 6 and Table A2 in the Appendix):

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[23] One by one as well as in groups.

[24] For the sake of convenience we present the results for the basic model version here. The extended version (including POPDENS, INDDENS and STUPINT) yields similar results.

[25] In order to control our results we also worked with a different definition of high knowledge, including only sectors with an above-average employment share of natural scientists and technicians (Biotech, Industrials&Industrial Services, Technology, according to Table A1 in the Appendix). The results for this more narrow definition of knowledge intensive sectors resemble those given in Table 4 and are available from the authors upon request.

[26] These are the sectors Financial Services, Media&Entertainment, Technology, Telecommunications, MedTech&Health Care.

Table 6: *Regression Models Estimating Firm Growth for High- and Low-Knowledge Sectors (agglomeration variable: HC)*

	Subsample of particularly knowledge intensive sectors			Subsample of sectors with below average knowledge intensity		
Dependent Variable	Model (11) OLS *GROWTH*	Model (12) Heckit *GROWTH*	Model (13) Probit *SURVIVAL*	Model (14) OLS *GROWTH*	Model (15) Heckit *GROWTH*	Model (16) Probit *SURVIVAL*
Constant	4.599*** (0.472)	5.067*** (0.693)	0.814 (0.735)	4.373*** (0.383)	4.748*** (0.545)	0.545 (0.759)
AGE	−0.099** (0.050)	−0.089 (0.073)	−0.013 (0.130)	−0.028 (0.055)	−0.051 (0.076)	0.065 (0.145)
SIZE	−1.189*** (0.217)	−1.234*** (0.256)	0.179 (0.121)	−1.101*** (0.191)	−1.125*** (0.212)	0.082 (0.132)
SIZESQRD	0.098*** (0.024)	0.097*** (0.028)	–	0.090*** (0.023)	0.088*** (0.027)	–
EAST	−0.269* (0.157)	−0.280 (0.247)	–	−0.077 (0.179)	−0.098 (0.216)	–
VC	−0.083 (0.151)	−0.068 (0.199)	–	−0.163 (0.149)	−0.146 (0.223)	–
HC	0.341*** (0.121)	0.324** (0.163)	–	−0.015 (0.122)	−0.012 (0.171)	–
LAMBDA	–	−1.120 (0.905)	–	–	−1.007 (0.819)	–
OTNMF	–	–	0.334 (0.5013)	–	–	0.553 (0.555)
IISMS	–	–	−0.815* (0.471)	–	–	−0.690** (0.342)
	$R^2 = 0.555$ Adj. $R^2 = 0.531$ F[6,110] = 22.87	$R^2 = 0.567^a$ Adj. $R^2 = 0.539$ F[7,109] = 32.58 20.39	McFadden: 0.0650 Veall/Zim.: 0.1105	$R^2 = 0.585$ Adj. $R^2 = 0.556$ F[6,88] = 37.26 20.63	$R^2 = 0.596^a$ Adj. $R^2 = 0.563$ F[7,87] = 32.76 18.32	McFadden: 0.0971 Veall/Zim.: 0.1572
	N = 117	N = 117	N = 135	N = 95	N = 95	N = 108

Note: Standard errors, robust to heteroskedasticity, are reported in parentheses. ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively.
[a] Not using OLS. R^2 is not bound in [0,1].

Source: Same as for Table 2. Own calculations.

Neither the degree of regional human capital (*HC*) nor the amount of "Neuer Markt" employment (*NME*) has a statistically significant impact on the growth of firms in low-knowledge sectors.

These results corroborate our second hypothesis that the impact of location on firm growth is greater in industries that are more knowledge intensive. We consider this a plausible result since industries where knowledge is not an important factor of production provide ceteris paribus less of a potential for knowledge spillovers and possess less absorptive capacity than knowledge-rich industries.

5 Conclusions

Two highly prominent literatures have generated something of a paradox. On the one hand, the new economic geography and endogenous growth literature suggest that spatial growth will be greater where knowledge spillovers are higher. However, the actual mechanisms by which this growth takes place at the microeconomic or firm level have remained vague and unclear. On the other hand, there is an extensive literature focusing on growth at the firm level, which has virtually ignored spatial externalities and instead focused almost exclusively on firm-specific characteristics, such as size and age, and to a lesser degree on industry specific characteristics.

The results of this paper suggest that it is useful to bring these two literatures together. In fact, firm performance, as measured by growth, does appear to be influenced by locational characteristics as well as characteristics specific to the firm and the industry. In particular, the empirical evidence suggests that being located in an agglomeration rich in knowledge resources is more conducive to firm growth than being located in a region that is less endowed with knowledge resources. In other words: *Regions abundant in knowledge resources appear to provide a particularly fertile soil for the growth of young, technology-oriented firms.* These results suggest the economic value of location as a mechanism for accessing external knowledge resources, which in turn, manifests itself in higher rates of growth.

An important qualification is that these results are most apparent for German publicly listed small and young firms in the most knowledge-intensive industries. Whether location has a similar impact on firm performance in a different sectoral (e.g., traditional industries) and institutional setting remains to be determined by subsequent research.

Appendix

Table A1: *Knowledge-Intensive Sectors According to Different Definitions*

	Definition 1 Above average percentage of academics	Definition 2 Above average percentage of natural scientists and technicians
Biotech	**51.5**	**68.5**
Financial Services	37.0	0
Internet	**48.1**	13.9
Industrials&Industrial Services	**43.9**	**54.8**
Media&Entertainment	28.4	8.8
Technology	30.7	**38.6**
IT Services	**55.2**	7.0
Telecommunications	n.a.	21.5
MedTech&Health Care	14.5	14.5
Software	**56.6**	17.2
"Neuer Markt" average	42.1	29.1

Source: Survey by RBSC (2002).

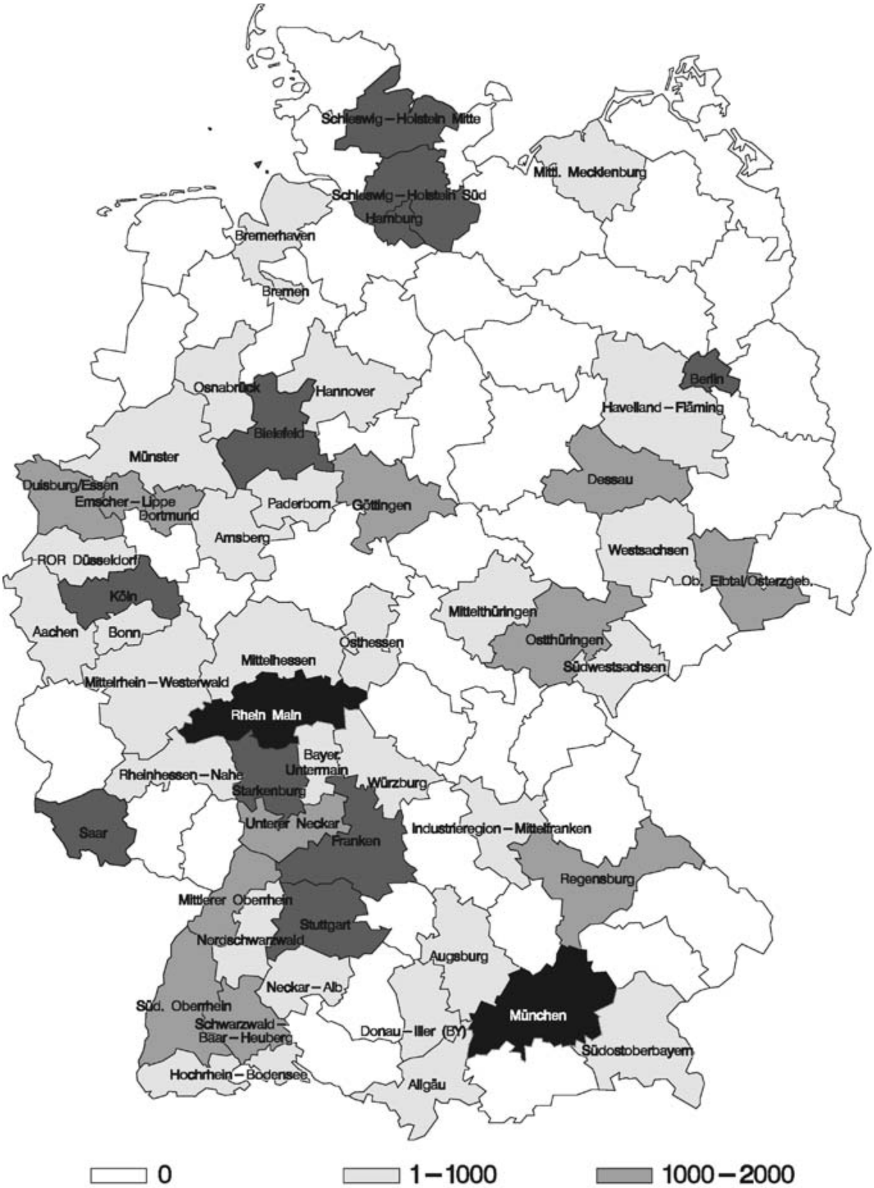
Table A2: *Regression Models Estimating Firm Growth for High- and Low-Knowledge Sectors (agglomeration variable: NME)*

	Subsample of particularly knowledge intensive sectors			Subsample of sectors with below average knowledge intensity		
Dependent Variable	OLS *GROWTH*	Heckit *GROWTH*	Probit *SURVIVAL*	OLS *GROWTH*	Heckit *GROWTH*	Probit *SURVIVAL*
ONE	4.061***	4.560***	0.814	4.160***	4.562***	0.545
	(0.545)	(0.807)	(0.735)	(0.504)	(0.704)	(0.759)
AGE	−0.113**	−0.103	−0.013	−0.028	−0.050	0.065
	(0.051)	(0.073)	(0.130)	(0.056)	(0.075)	(0.145)
SIZE	−1.196***	−1.241***	0.179	−1.093***	−1.119***	0.082
	(0.217)	(0.257)	(0.121)	(0.195)	(0.211)	(0.132)
SIZESQRD	0.096***	0.094***	–	0.090***	0.088***	–
	(0.024)	(0.029)		(0.023)	(0.026)	
EAST	−0.064	−0.085	–	−0.071	−0.093	–
	(0.140)	(0.246)		(0.166)	(0.207)	
VC	−0.171	−0.151	–	−0.226	−0.199	–
	(0.159)	(0.217)		(0.170)	(0.234)	
NME	0.113**	0.107*	–	0.028	0.024	–
	(0.045)	(0.059)		(0.047)	(0.058)	
LAMBDA	–	−1.130	–	–	−0.991	–
		(0.911)			(0.813)	
OTNMF	–	–	0.334	–	–	0.553
			(0.501)			(0.555)
IISMS	–	–	−0.815*	–	–	−0.690**
			(0.471)			(0.342)
	R^2 = 0.552 Adj. R^2 = 0.528 F[6,110] = 22.61	R^2 = 0.564[a] Adj. R^2 = 0.536 F[7,109] = 20.18	McFadden: 0.0650 Veall/Zim.: 0.1105	R^2 = 0.586 Adj. R^2 = 0.558 F[6,88] = 20.75	R^2 = 0.597[a] Adj. R^2 = 0.564 F[7,87] = 18.40	McFadden: 0.0971 Veall/Zim.: 0.1572
	N = 117	N = 117	N = 135	N = 95	N = 95	N = 108

Note: Standard errors, robust to heteroskedasticity, are reported in parentheses. ***, **, * indicate significance at the 1, 5, and 10 percent level, respectively.
[a] Not using OLS. R^2 is not bound in [0,1].

Source: Same as for Table 2. Own calculations.

Figure A1: *Geographic Distribution of Employment in "Neuer Markt" Firms, 2002*



Data source: See Table 1.

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