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ABSTRACT

The Impact of Location on Firm Growth

This Paper links the performance of new technology firms, measured in terms of 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 new dataset identifying the growth performance of small technology-based firms. In fact, 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.

JEL Classification: L10, O12, O30 and R11
Keywords: agglomeration, firm growth and knowledge spillovers

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1. Introduction

The last decade has seen an explosion of interest in economic growth for a diversity of units of observation. While the Endogenous Growth Theory (Romer, 1986 and 1990) and New Economic Geography (Krugman, 1991 and 1998) focuses 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. An important finding in both the endogenous growth literature as well as the studies on city growth is 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 virtually nothing known about the impact of location on growth at the micro or establishment level.

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 establishment 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. Insights about the impact of location in general, and agglomerations in particular on firm growth have been limited.

This omission cannot be attributed to a lack of theories and empirical evidence about growth at the firm level. 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.

The purpose of this paper is to fill 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. This data set mainly includes technology firms to reflect the findings from the literature (Audretsch and Feldman, 1996) suggesting knowledge activities tend to benefit more from agglomeration than do non-knowledge activities, at least in manufacturing. We anticipate that the results from this paper will add considerable value to the scholarly literatures on growth at both the spatial and enterprise levels by showing the impact that location plays on the growth of technology firms.

2. The Locational Impact on Firm Growth

In response to a literature that focused on static relationships, Mansfield (1962, p. 1023) made a plea some 40 years ago for a greater emphasis on understanding the dynamic performance of industries that underlie 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 survived 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.

In his exhaustive survey in the *Journal of Economic Literature*, Sutton (1997, p. 43) interpreted Gibrat's Law as rather than constituting a bona fide Law, it is an assumption that the probability of 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, pp. 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 the process of learning from the actual post-entry performance. The new firm will typically have a small startup 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 of 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; and Bartik, 1989). 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. 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, Kallal, Scheinkman, and Schleifer (1992, p. 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. Undoubtedly among these three forces which are hypothesized by Marshall to increase firm growth, knowledge spillovers are the most essential for the small high-tech firm growth.

A plethora of empirical studies over the past decade have confirmed the existence and magnitude of knowledge spillovers. 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), Jaffee, Trajtenberg and Henderson (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 have superior access to both knowledge resources as well as knowledge spillovers. This leads to the two fundamental hypotheses of this proposal. First, 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. Second, 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 will provide less of a potential for knowledge spillovers.

To identify the locational impact on firm growth, we propose a model linking firm growth to characteristics specific to the enterprise, industry and location. The starting point is the most prevalent model for identifying the determinants of growth at the level of the firm, which has been based to test Gibrat's Law (Sutton, 1997).

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 a "proportional effect" and the initial firm size as:

$$\mathbf{Size_{i,t} = (1 + \varepsilon_t)\, Size_{i,t-1}} \quad (1)$$

where $(1 + \varepsilon_t)$ denotes the proportional effect for firm i in period t. Here the random shock ε_t is assumed to be identically and independently distributed. Taking the natural log and using the fact that for small ε, $\ln(1 + \varepsilon) \approx \varepsilon_t$, we derive the following relationship,

$$\mathbf{\ln(Size_{i,t}) = \ln(Size_{i,0}) + \sum_{k=1}^{t} \varepsilon_{ik}} \quad (2)$$

which as $t \rightarrow \infty$ results in a distribution which is approximately log normal with properties that $\ln(Size_{i,t}) \sim N(t\mu_\varepsilon, t\sigma^2_\varepsilon)$. [1]

Firm growth can then be measured as the difference between the log of the number of employees as:

$$\mathbf{Growth_{it} = \ln(S_{i,t}) - \ln(S_{i,t-1})} \quad (3)$$

where the difference in Size for firm i between the current period t and the previous period (t - 1) equals $Growth_{it}$.

Based on Hall (1987) and Evans (1987) the empirical growth equation for testing the hypothesis that initial firm size and age impact firm growth can be specified:

$$\mathbf{Growth_{i,t} = B_1 \ln(Size_{i,t-1}) + B_2 \ln(Size_{i,t-1})^2 + B_3 Age_{i,t-1} + \varepsilon_i} \quad (4)$$

where growth for firm i in period t is a function of initial firm size, $size^2$, age, and ε_i a stochastic error term.

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[1] Almus and Nerlinger (2000) confirm this distributional assumption via kernal density estimates for German firms 1990-1996.

Sutton (1997) and Caves (1998) survey and report on the large number of empirical studies estimating Equation (4). The evidence is systematic and compelling that both size and age are negatively related to firm growth. We will extend this standard model testing Gibrat's Law to incorporate locational elements as well. In particular, we will include the types of location-specific measures used by Carlton (1983), Bartik (1989), Reynolds, Storey and Westhead (1994), and Reynolds and Maki (1995). The location-specific variables will include measures reflecting the importance of knowledge and technology at that location.

Note that Equation 4 only considers characteristics specific to the enterprise. We extend this classical firm-specific approach by also considering industry-specific and location-specific determinants of growth. Our econometric model (basic version) has the form

$$\mathbf{Growth_{i,t} = B_1 \ln(Size_{i,t-1}) + B_2 \ln(Size_{i,t-1})^2 + B_3\, Age_{i,t-1} + B_4\, D_{ind} +}$$

$$\mathbf{B_5\, Knowledge_{r,\, t-1} + B_6\, X_{r,\, t-1} + \varepsilon_i} \qquad (5)$$

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 Equation 4, has implicitly assumed that location plays no role in shaping growth, Equation 5 reflects the major hypothesis of this paper whereby firm performance is enhanced in locations providing greater access to knowledge resources. 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. Positive coefficients on measures of knowledge factors and the degree of agglomeration would suggest that firm growth should be systematically and positively shaped by being located in regions rich in knowledge.

3. Data and Measurement

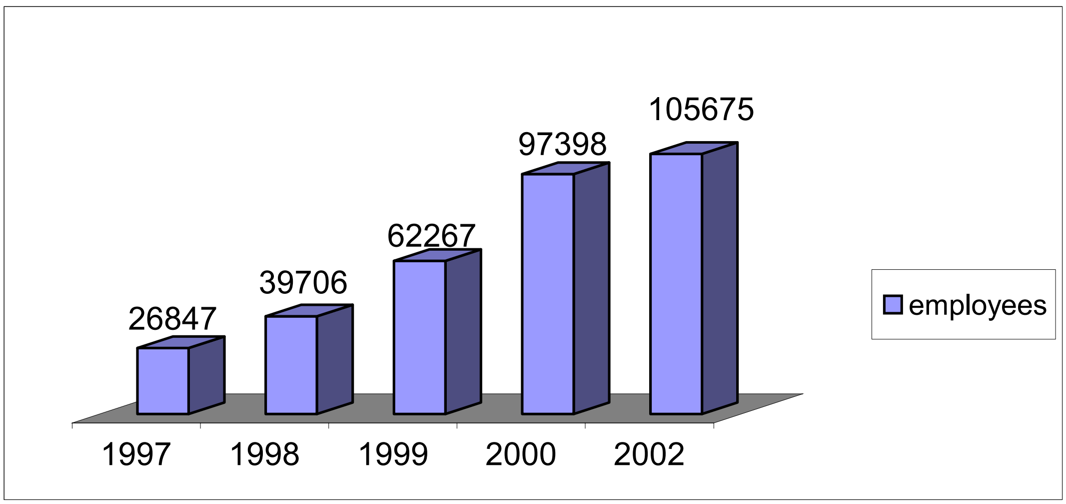
The main hypothesis derived in this paper is that location in a knowledge-rich agglomeration or cluster should enhance the performance of knowledge-intensive (technology) firms as a result of spillovers. If the firm is located within such a region it will have access to such spillovers. If it is not located in a knowledge-rich region its access to external knowledge will be more limited. Therefore, to examine the impact of location on firm performance, it is appropriate to use a data set consisting of young knowledge intensive (technology) firms. 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 1997-2002, we created such a data set.[2] Only

[2] 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

firms with their headquarters in Germany were considered. Most of the relevant data were publicly available from on-line 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. Therefore, we performed a supplementary e-mail survey to complete the data base between March and June 2003.

Figure 1 illustrates that the mean employment growth of the firms included in the data set between 1997-2002 was very high.

Figure 1: Persons Employed at Firms in The Sample



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

Table 1 shows that firm growth rates were highly specific to the particular sector. However, the question addressed in this paper is not why is the growth of these high technology enterprises so high, but, rather, is the growth performance of these firms shaped by location.

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the newly created indices TECDAX (for Blue Chips), Technology All Share Index and SDAX (a small cap index not restricted to technology firms).

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

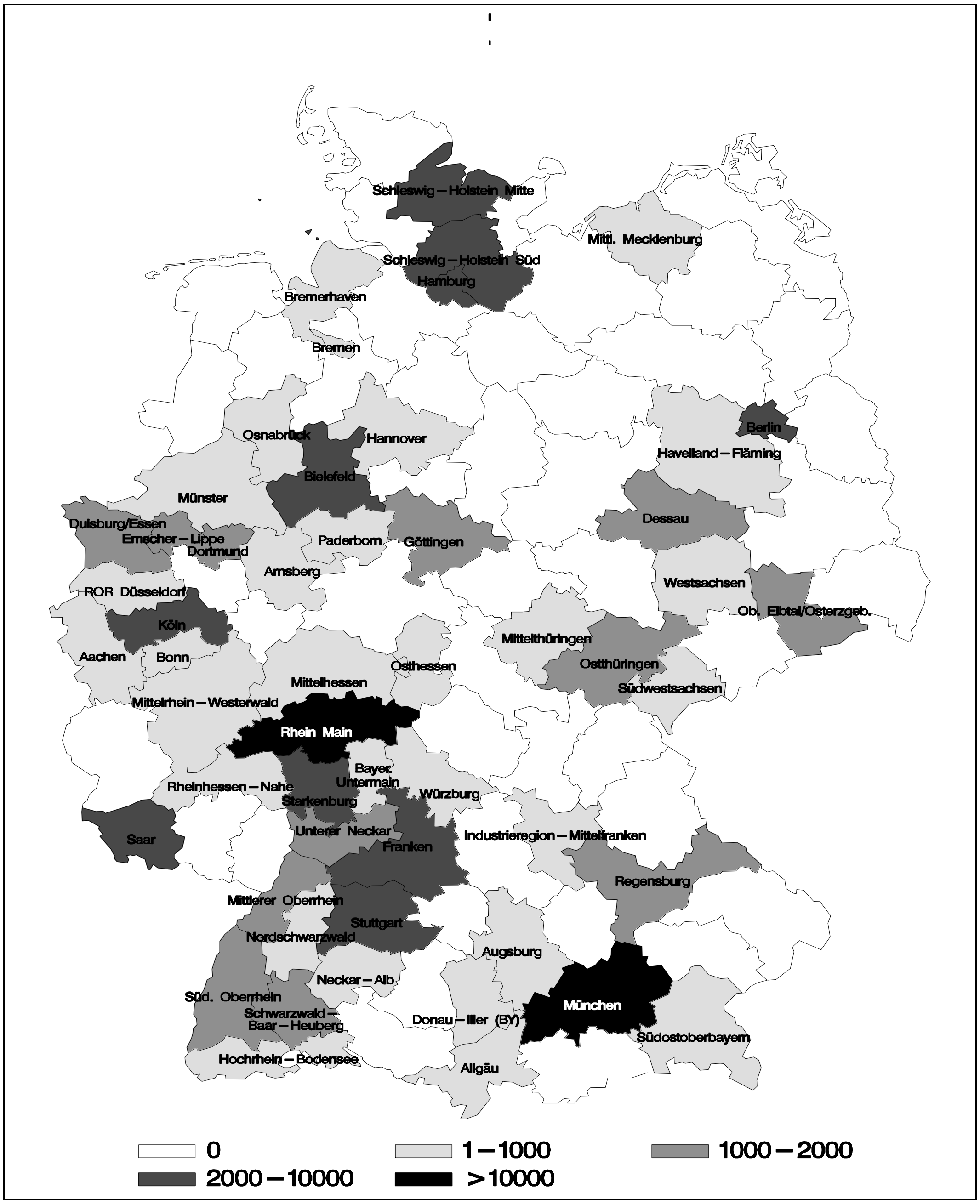
Sector	Compound Annual Growth Rate 1998-2002	Compound Annual Growth Rate 2000-2002	Number of Employees September 2002	Number of Firms September 2002
Biotech	46,5 %	17,2 %	3.005	14
Media&Entertainment	42,2 %	-12,4 %	4.560	26
Internet	41,8 %	-2,1 %	15.122	35
IT Services	31,2 %	8,3 %	15.297	26
Financial 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

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

Figure 2 shows the distribution of employment in the data base across the 97 German planning regions.[3]

Figure 2: Geographic Distribution (Employment, 2002)

[3] The average number of *Neuer Markt* employees per planning region is 1089. The leading region (Munich) has more than 20.000 employees, wheras 44 planning regions do not host any Neuer Markt firms at all.



Source: Same as for table 1.

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 (size and age) to performance (growth) as specified in Equation 4. This is presented in Equation 5. In addition to the measure of firm age (1997) and firm size (employment in 1997), industry- and region-specific measures are included. 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 (see table A1 in the appendix for more details) and a value of 0 otherwise.

We use a number of *region-specific* measures reflecting the knowledge resources and other spillover sources of the region, including a dummy variable for regions with a skilled labor force share in the highest 20 percent (HUMAN CAPITAL), the amount of employment in the region accounted for by *Neuer Markt* firms (NM-EMPLOY), a dummy variable for the presence of venture capital in the region (VC), and the high technology start up rate of the region (GRINTST). In addition, a dummy variable for firms with a location in one of the five new eastern states (the former East Germany) is also included (DOST).[4]

Table 2 shows that the correlation between the explanatory variables is relatively low, implying that multicollinearity is not a major problem in the estimated regressions**.**

Table 2: Correlation Matrix

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**Growth**	1,00									
2	**Age**	-0,38	1,00								
3	**Size**	-0,61	0,47	1,00							
4	**Size, squared**	-0,54	0,44	0,97	1,00						

[4] Table A3 in the appendix provides an overview over and exact definitions of the variables used in the regressions.

5	**KI-Sector**	0,06	0,14	0,11	0,12	1,00					
6	**High Tech start ups**	-0,01	0,00	-0,04	-0,06	0,01	1,00				
7	**VC Dummy**	-0,01	-0,01	-0,01	0,00	-0,17	-0,01	1,00			
8	**East Germany Dummy**	-0,09	-0,01	0,09	0,08	-0,07	-0,27	0,06	1,00		
9	**Neuer Markt Employment**	0,09	0,03	0,01	0,03	-0,14	0,30	0,51	-0,08	1,00	
10	**Human Capital**	0,16	-0,13	-0,11	-0,10	-0,15	0,01	0,37	0,25	0,66	1,00

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

4. Results

4.1 Growth conditional on survival

Table 3 shows the results of estimating the impact of location on firm growth, 1997-2002, for the publicly listed German firms. To estimate the growth equation, the natural logs of each independent variable is used, other than for the dummy variables.

It should be emphasized that we use two distinct measures of agglomeration. This is because human capital (percentage of highly qualified employees) 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.

In a first step we estimated firm growth using OLS estimation (see models (1) and (4) in table 3). The results seem to corroborate our two fundamental hypotheses outlined in section 2.

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 suggests that growth tends to decrease more slowly as the firms become larger. [5]

The positive and statistically significant coefficient of *human capital* 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 in the region, is used (model 4). Thus, both measures indicate that firm growth is positively influenced by being located in an agglomeration.

As the insignificant coefficients indicate, there is no evidence that the presence of venture capital influences the growth rates. The East Germany dummy has a negative sign and is weakly significant (at the 10% level) in model 1, but is insignificant in all other model specifications.[6]

[5] 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.

[6] Moreover, including start up intensity (GRINTST) as additional explanatory variable does not lead to any significant changes in the results.

Table 3: Regression Models Estimating Firm Growth and Survival

	Agglomeration Variable: Human Capital			Agglomeration Variable: Neuer Markt Employment		
Model	(1) OLS	(2) Heckit	(3) Probit	(4) OLS	(5) Heckit	(6) Probit
Dependent Variable	Growth	Growth	Survival	Growth	Growth	Survival
	Coeff (StdErr)[a] [P-value]	Coeff (StdErr) [P-value]	Coeff (StdErr) [P-value]	Coeff (StdErr)[a] [P-value]	Coeff (StdErr) [P-value]	Coeff (StdErr) [P-value]
Constant	4.206 (0.339) [0.000]	3.950 (0.466) [0.000]	0.557 (0.494) [0.260]	3.770 (0.410) [0.000]	3.325 (0.585) [0.000]	0.557 (0.494) [0.260]
AGE	-0.086 (0.037) [0.020]	-0.086 (0.039) [0.027]	0.016 (0.096) [0.864]	-0.097 (0.0367) [0.009]	-0.097 (0.042) [0.021]	0.016 (0.096) [0.864]
SIZE	-1.049 (0.155) [0.000]	-1.019 (0.139) [0.000]	0.143 (0.087) [0.099]	-1.030 (0.158) [0.000]	-0.980 (0.143) [0.000]	0.143 (0.087) [0.099]
SIZESQRD	0.083 (0.017) [0.000]	0.082 (0.016) [0.000]	-	0.080 (0.018) [0.000]	0.078 (0.016) [0.000]	-
KIS	0.230 (0.089) [0.010	0.300 (0.138) [0.029]	-	0.234 (0.089) [0.009]	0.344 (0.146) [0.018]	-
DOST	-0.205 (0.121) [0.091]	-0.192 (0.140) [0.171]	-	-0.091 (0.111) [0.416]	-0.064 (0.140) [0.647]	-
VC	-0.081 (0.103) [0.434]	-0.064 (0.128) [0.615]	-	-0.134 (0.113) [0.238]	-0.121 (0.137) [0.378]	-
HUMAN CAPITAL	0.218 (0.084) [0.010]	0.222 (0.102) [0.029]	-	-	-	-
NM-EMPLOY	-	-	-	0.075 (0.033) [0.025]	0.082 (0.036) [0.021]	-
LAMBDA	-	0.485 (0.699) [0.487]	-	-	0.741 (0.744) [0.319]	-
OTNMF	-	-	0.446 (0.367) [0.225]	-	-	0.446 (0.367) [0.225]
IISMS	-	-	-0.610 (0.238) [0.010]	-	-	-0.610 (0.238) [0.010]
	R^2=0.561 Adj. R^2=0.546 F[7,204]=37.25	R^2=0.562[b] 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[b] Adj. R^2=0.546 F[8,203]=32.76	McFadden: 0.072 Veall/Zim: 0.1205

a) Corrected for heteroscedasticity.
b) Not using OLS. R^2 is not bound in [0,1].

Data sources: Same as for table 2. Own calculations.

However, as the positive and statistically significant coefficients suggest, firm growth is influenced by the knowledge intensity (KIS) of the sector. A possible interpretation of this result — in line with theoretical models such as Ericson and Pakes (1995) — is that young firms that have made investments in active learning (by employing a particular high portion of natural scientists, technicians and engineers) experience faster growth**.**

4.2 Unconditional Growth

In models (1) and (4) we have only considered *Neuer Markt* firms that survived until September 2002, i.e. we have analysed *growth conditional on survival*. However, an important qualification is that various *Neuer Markt* firms closed or went bankrupt in the period under consideration (1997 until 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 31 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) obtained from step 1 as a correction factor (see Wooldridge 2002, p. 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, 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 3, the most important variable in explaining survival (or exit, respectively) is the sector dummy for Internet, Media and Software firms (IISMS), which has a negative sign and is highly significant. 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 % level). All other variables have no significant impact on survival.[7]

The results of the Heckit estimation of firm growth (models (2) and (5) in table 3) 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 of agglomeration on firm growth discussed 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 High knowledge versus low knowledge sectors

Since knowledge spillovers are presumably less important in sectors where knowledge does not play an important role, in Table 4 firms in the high knowledge intensive sectors are separated from low knowledge sectors. High-knowledge is defined as the sub-sample 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,

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[7] Note that models (3) and (6) in table 3 are identical since the different agglomeration variables are no arguments of the survival function.

Table 4: Regression Models Estimating Firm Growth for High and Low Knowledge Sectors (Agglomeration variable: HUMAN CAPITAL)

	Subsample of particularly knowledge intensive sectors			Subsample of sectors with below average knowledge intensity		
Model	(7)OLS	(8)Heckit	(9)Probit	(10)OLS	(11)Heckit	(12)Probit
Dependent Variable	Growth	Growth	Survival	Growth	Growth	Survival
	Coeff. (Std.Err.)[a] [P-value]	Coeff. (Std.Err.) [P-value]	Coeff. (Std.Err.) [P-value]	Coeff. (Std.Err.)[a] [P-value]	Coeff. (Std.Err.) [P-value]	Coeff. (Std.Err.) [P-value]
CONSTANT	4.599 (0.472) [0.000]	5.067 (0.693) [0.000]	0.814 (0.735) [0.268]	4.373 (0.383) [0.000]	4.748 (0.545) [0.000]	0.545 (0.759) [0.473]
AGE	-0.099 (0.050) [0.049]	-0.089 (0.073) [0.217]	-0.013 (0.130) [0.919]	-0.028 (0.055) [0.613]	-0.051 (0.076) [0.505]	0.065 (0.145) [0.652]
SIZE	-1.189 (0.217) [0.000]	-1.234 (0.256) [0.000]	0.179 (0.121) [0.137]	-1.101 (0.191) [0.000]	-1.125 (0.212) [0.000]	0.082 (0.132) [0.535]
SIZESQRD	0.098 (0.024) [0.000]	0.097 (0.028) [0.001]	–	0.090 (0.023) [0.000]	0.088 (0.027) [0.000]	–
DOST	-0.269 (0.157) [0.090]	-0.280 (0.247) [0.257]	–	-0.077 (0.179) [0.669]	-0.098 (0.216) [0.650]	–
VC	-0.083 (0.151) [0.584]	-0.068 (0.199) [0.732]	–	-0.163 (0.149) [0.277]	-0.146 (0.223) [0.513]	–
HUMAN CAPITAL	0.341 (0.121) [0.006]	0.324 (0.163) [0.047]	–	-0.015 (0.122) [0.904]	-0.012 (0.171) [0.945]	–
LAMBDA	–	-1.120 (0.905) [0.216]	–	–	-1.007 (0.819) [0.219]	–
OTNMF	–	–	0.334 (0.5013) [0.505]	–	–	0.553 (0.555) [0.319]
IISMS	–	–	-0.815 (0.471) [0.083]	–	–	-0.690 (0.342) [0.044]
	R^2=0.555 Adj.R^2=0.531 F[6,110]= 22.87	R^2=0.567[b] Adj.R^2=0.539 F[7,109]= 20.39	McFadden: .0650 Veall/Zim.: .1105	R^2=0.585 Adj.R^2=0.556 F[6,88]= 20.63	R^2=0.596[b] Adj.R^2=0.563 F[7,87]= 18.32	McFadden: .0971 Veall/Zim.: .1572

a) Corrected for heteroscedasticity.
b) Not using OLS. R^2 is not bound in [0,1].

Data sources: Same as for table 2. Own calculations.

Software, Internet, Industrials&Industrial Services and IT-Services. [8] Accordingly, sectors with a below-average employment share of academics are labelled “low knowledge” sectors.

As the positive and statistically significant coefficients of regional human capital indicate, the growth of knowledge intensive firms is higher in regions with a high agglomeration of knowledge assets (models (7) and (8) in Table 4). The same holds when we use *Neuer Markt* employment 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 (10 and (11) in table 4 and table A2 in the appendix): Neither the degree of regional human capital nor the amount of *Neuer Markt* employment 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 will provide less of a potential for knowledge spillovers and possess less absorptive capacity than knowledge-rich industries.

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[8] 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.

5. Conclusions

Two highly prominent literatures have generated something of a paradox. On the one hand, the new economic geography and endogenous growth literature suggests 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. 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 institutional context remains to be determined by subsequent research.

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Appendix

Table A1: Knowledge intensive sectors according to different definitions

Sector	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 Roland Berger Strategy Consultants 2002

Table A2: Regression Models Estimating Firm Growth for High and Low Knowledge Sectors (Agglomeration variable: NEUER MARKT EMPLOYMENT)

	Subsample of particularly knowledge intensive sectors			**Subsample of sectors with below average knowledge intensity**		
Model	OLS	Heckit	Probit	OLS	Heckit	Probit
Dependent Variable	Growth	Growth	Survival	Growth	Growth	Survival
	Coeff. (Std.Err.) [a] [P-value]	Coeff. (Std.Err.) [P-value]	Coeff. (Std.Err.) [P-value]	Coeff. (Std.Err.) [a] [P-value]	Coeff. (Std.Err.) [P-value]	Coeff. (Std.Err.) [P-value]
ONE	4.061 (0.545) [0.000]	4.560 (0.807) [0.000]	0.814 (0.735) [0.268]	4.160 (0.504) [0.000]	4.562 (0.704) [0.000]	0.545 (0.759) [0.473]
LNAGE	-0.113 (0.051) [0.028]	-0.103 (0.073) [0.159]	-0.013 (0.130) [0.919]	-0.028 (0.056) [0.614]	-0.050 (0.075) [0.501]	0.065 (0.145) [0.652]
SIZE	-1.196 (0.217) [0.000]	-1.241 (0.257) [0.000]	0.179 (0.121) [0.137]	-1.093 (0.195) [0.000]	-1.119 (0.211) [0.000]	0.082 (0.132) [0.535]
SIZESQRD	0.096 (0.024) [0.000]	0.094 (0.029) [0.001]	–	0.090 (0.023) [0.000]	0.088 (0.026) [0.001]	–
DOST	-0.064 (0.140) [0.647]	-0.085 (0.246) [0.728]	–	-0.071 (0.166) [0.668]	-0.093 (0.207) [0.653]	–
VC	-0.171 (0.159) [0.287]	-0.151 (0.217) [0.487]	–	-0.226 (0.170) [0.188]	-0.199 (0.234) [0.395]	–
NM-EMPLOY	0.113 (0.045) [0.014]	0.107 (0.059) [0.069]	–	0.028 (0.047) [0.548]	0.024 (0.058) [0.681]	–
LAMBDA	–	-1.130 (0.911) [0.215]	–	–	-0.991 (0.813) [0.223]	–
OTNMF	–	–	0.334 (0.5013) [0.505]	–	–	0.553 (0.555) [0.319]
IISMS	–	–	-0.815 (0.471) [0.083]	–	–	-0.690 (0.342) [0.044]
	R^2=0.552 Adj.R^2=0.528 F[6, 110] = 22.61	R^2= 0.564[b] Adj.R^2=0.536 F[7, 109] = 20.18	McFadden: .0650 Veall/Zim.: .1105	R^2=0.586 Adj.R^2=0.558 F[6, 88] = 20.75	R^2= 0.597[b] Adj.R^2=0.564 F[7, 87] = 18.40	McFadden: .0971 Veall/Zim.: .1572

a) Corrected for heteroscedasticity.
b) Not using OLS. R^2 is not bound in [0,1].

Data sources: Same as for table 2. Own calculations.

Table A3: Variables Used in the Regressions

Dependent Variables

Growth	= ln (firm size)$_t$ - ln (firm size)$_{t-1}$
Survival	= 1, if firm has survived until September 2002 = 0, if firm hasn't survived

Firm specific variables

AGE	= ln (firm age)$_{t-1}$
SIZE	= ln (firm size)$_{t-1}$
SIZESqrd	= square of ln (firm size)$_{t-1}$

Sector specific variables

KIS	= dummy for particularly knowledge intensive sectors (sectors with employment share of scientists and engineers above Neuer Markt average; see table A1)
IISMS	= Sector dummy Internet + Media + Software

Region specific variables

DOST	= dummy for east Germany
GRINTST	= start up intensity in the high tech sector
HUMAN CAPITAL	= dummy for regions with above average share of highly qualified labor (top 20% of regions)
NM-EMPLOY	= ln (Neuer Markt employment in the region)
OTNMF	= dummy for other Neuer Markt firms in the region
VC	= dummy for venture capital firms in the region
LAMBDA	= inverse Mills ratio correction term