Exploring the Knowledge Filter: How Entrepreneurship and University-Industry Relations Drive Economic Growth

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Abstract:

Knowledge is recognized as a crucial element of economic growth in addition to physical capital and labor. Knowledge can be transformed into products and processes and is herewith exploited commercially. The ability to produce, identify, and exploit knowledge depends on the existing knowledge stock and the absorptive capacity of actors like employees at firms and researchers at universities and research institutions. The existing knowledge stock might not be commercialized to its full extent, therefore, knowledge flows must occur and transmission channels are needed. The paper tests the hypotheses that entrepreneurship and university-industry relations are vehicles for knowledge flows and thus spur economic growth.

JEL classification: M13, O18, O31
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1 Introduction*

Why do regions post different growth rates and differences in technological progress? The growth rates of labor and physical capital are not the only sources of economic growth; in fact, knowledge creation, knowledge flows, and the capitalization of knowledge are an important element in stimulating economic development. Recent empirical studies (Plummer and Acs, 2004; Varga and Schalk, 2004; Acs and Varga, 2004; Audretsch and Keilbach, 2004) have shown that knowledge spillovers positively affect technological change and economic growth.[1] However, other studies have shown that knowledge spillovers do not occur automatically (i.e. Anselin, Varga and Acs, 1997 and 2000; Audretsch and Feldman, 1996). Hence, it is less obvious which mechanisms facilitate and foster knowledge flows.

This paper focuses on the exploitation of opportunities and the capitalization of knowledge, namely the transformation of knowledge into products, processes, and organizations and their contribution to regional economic growth. One reason for different degrees of knowledge capitalization across regions might be that a varying level of research and development activities exists across regions. A high level of research and development leads to innovations and facilitates the ability to identify, absorb, and exploit internally and externally generated knowledge, i.e. created by other firms or research institutions (see Cohen and Levinthal, 1989). Another reason might be that incumbent firms do not exploit new knowledge to the full extent and new knowledge generated in research institutions and universities is not commercialized at all. A critical part of knowledge may lie idle and, thus, knowledge flows are necessary for its diffusion. Mechanisms are needed in order to support the exploitation of opportunities. This paper introduces entrepreneurship and university-industry relations as mechanisms for knowledge

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[1] Audretsch and Lehmann (2005) have shown that knowledge spillovers from universities affect firm growth. Firms that are closely located to the next university experience higher growth rates.

flows and knowledge capitalization, and therefore, determinants of economic growth.

The remainder of the paper is organized as follows. Section 2 presents the theoretical framework and links channels for knowledge flows to economic growth. The methodology and database is described in section 3. It is empirically tested if entrepreneurship and university-industry relations are mechanisms facilitating the spillover of knowledge and affect economic growth in section 4. Section 5 provides a summary and a conclusion.

2 The Capitalization of Knowledge: The Significance of Knowledge Flows and the Knowledge Filter

Although knowledge is understood as an essential driver of economic growth, it is hardly linked to economic growth in empirical analyses. Within the new growth theory, knowledge stimulates technological progress and, thus, increases productivity.[2] New knowledge generates innovations and is capitalized by transforming it into new products, processes, and organizations. Private businesses, universities, and other research institutions generate new knowledge through research and development activities. The created knowledge may be exploited by them, the knowledge-producer, or by other organizations. These other organizations can be in the same industry, related or different industries or disciplines. However, the possibility to exploit knowledge from the environment requires it to flow, i.e. knowledge spillovers. These spillovers allow other economic actors to exploit the newly created knowledge as well, resulting in an acceleration of economic growth.

Cohen and Levinthal (1989) argue that research and development activities not only generate innovations but also increase the firm's ability to identify, assimilate, and exploit externally created knowledge.[3] Applied on the regional level, this would indicate that the higher the level of research and development

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[2] Romer (1986, 1990) and Lucas (1988) explain economic growth in their models through the accumulation and spillover of technological knowledge.

[3] See also Cohen and Levinthal (1990) and Zucker, Darby and Brewer (1998) for more details on absorptive capacity.

activities in a region are, results in more knowledge that can be exploited by the knowledge-creator or other actors, for instance other businesses. In other words, the regional level of R&D characterizes the region’s absorptive capacity. However, knowledge may be subject to various constraints preventing knowledge spillovers; namely legal, cost, and geographical constraints. Patenting, the protection of intellectual property, may be one legal constraint (Cohen, Nelson and Walsh, 2002a) and a financial constraint since other firms need to pay license fees. The deployed technology, the factual production capacity, or the qualification level of the employees also affect the exploitation of knowledge. Results of various empirical analyses show that knowledge spillovers are spatially bounded (Anselin, Varga and Acs, 1997 and 2000; Audretsch and Feldman, 1996 and 2004; Audretsch and Lehmann, 2005)[4]. Knowledge spillovers seem to depend on a strong regional component, taking advantage of spatial proximity to research facilities, universities, and industry specific agglomerations. Analyzing patent citations, Jaffe et al. (1993) found that knowledge spillovers from academic research to private industries have a strong regional component (see also Arundel and Geuna, 2004, for the importance of proximity for the use of public science). The argued explanation for the regional localization of knowledge is usually the tacit nature of knowledge which requires direct, inter-personal contacts to be obtained (Anselin, Varga and Acs, 1997, 2000; Maskell and Malmberg, 1999; Hippel, 1987, Senker, 1995). Arundel and Geuna (2004) propose that as long as there is a delay between the discovery of knowledge and its codification, inter-personal interactions are premier mechanisms for knowledge flows. Due to this delay in time proximity may be relevant because local, direct and inter-personal contacts enable businesses to access knowledge faster and more successful and business are more likely to know where to access new knowledge.[5]

Furthermore, knowledge may not be fully applied or exploited. One reason could be that incumbent firms do not want to take the risk combined with new products or processes. They might focus on exploiting the profit possibilities of their given product program and they are not interested in searching for new

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[4] See also Jaffe, Trajtenberg & Henderson (1993); Audretsch, Lehmann and Warning (2004).

[5] See Gorman (2002) for an overview of the different types of knowledge.

opportunities and realizing them (Audretsch, 1995; Geroski, 1995, 431). Internal constraints (i.e. financial manner) might also hinder the commercialization of knowledge in these firms. Another reason might be that the research at universities and research institutions, in particular, is hardly translated into new products or services (Pavitt, 2001). The primary mission of universities is research and education and not the capitalization of their generated knowledge. Many universities are nowadays actively developing to extend their research into the development process (see also Etzkowitz, 1998). In order to utilize academic research in a commercial manner and to foster its capitalization, university-industry partnerships or the set-up of university spin-off companies are needed.[6] Mansfield (1991 and 1998) and Beise and Stahl (1999) point out that some new products and processes would not have been developed without academic research or only with substantial delay and without technology transfer. Therefore, it may be proposed that a kind of filter exists, functioning as a barrier and limiting the total conversion of knowledge into new products, processes, and organizations. Acs et al. (2005) call this barrier a knowledge filter.[7]

The permeability of the knowledge filter determines to what extent knowledge is exploited commercially, and the permeability may be increased by a greater pool of economic actors possessing the ability and willingness to take the risk and exploit the knowledge. Since knowledge needs to flow before it can be applied and commercialized externally, the existence of knowledge transmission channels is crucial. This paper suggests that new business formation and university-industry relations are possible transmission channels, which penetrate the knowledge filter and stimulate knowledge flows.

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[6] See for instance Rosenberg and Nelson (1994); Hall, Link and Scott (2003), or Arundel and Geuna (2004) for university-industry research partnerships. See Meyer (2003) for university spin-offs as a mechanism to capitalize university knowledge.

[7] Acs et al. (2005) developed a model in which knowledge is transformed into economically useful knowledge by either incumbent firms or start-ups. Incumbent firms learn, increase their absorptive capacity and incorporate new knowledge into their firm-specific knowledge, thus they absorb knowledge spillovers. New ventures are assumed to be the mechanism to transmit knowledge and transform it through knowledge spillovers into economically relevant knowledge. However, for Acs et al. knowledge spillovers cannot occur without new ventures, and hence, there is no economic growth.

Entrepreneurial activity, taking the opportunity and setting up a business, can be assumed as a mechanism by which knowledge spillover and the capitalization of knowledge occurs. Founders of the new ventures might have worked for incumbent firms or universities before they commercialize the new knowledge , i.e. university spin-off. Through their innovative activity, new ventures may introduce new products or even create new markets. Many radical innovations have been introduced by new firms rather than by incumbents (Audretsch, 1995). This phenomenon may be explained that the set-up of one's own business might be the most promising – sometimes the only – possibility to commercialize knowledge (Audretsch, 1995). Studies of spin-offs have found that the reasons that cause individuals to leave their employer and to create their own firm are frustration with their current employer and the expectation of greater financial rewards (see Garvin, 1983; Klepper and Sleeper, 2005 for an overview). Particularly, frustration may arise among the scientists and engineers if their ideas about a new product or process are rejected by their supervisors or top management (see Garvin, 1983 for examples). Agarwal et al. (2004) found that, in particular, existing organizations with abundant knowledge, which is underexploited, represent a breeding ground for spin-offs.

University-industry relations may be the other mechanism facilitating the exploitation of knowledge and the flow of ideas (c.f. Mansfield and Lee, 1996; Fritsch and Lukas, 2001; Fritsch, 2001; Arundel and Geuna, 2004). Many governments try to obtain an increase in the interaction between university and industry (Cohen, Nelson and Walsh, 2002a), because these interactions are recognized to ascend the rate of innovation in the economy (Spencer, 2001 and Laursen and Salter, 2004). For example, the European Commission believes that European firms in comparison to their U.S. American counterparts fail to commercialize new knowledge generated in universities and other public research institutions (EC, 2001; see also Arundel and Geuna, 2004 for an analysis of the use of public science by firms within the European Union). Public research hardly results in ready-to-produce innovations; however, if the generated knowledge is transferred via research partnerships it may accelerate technology transfer and enable firms to develop new products and process (Cohen, Nelsen and Walsh, 2002a, Spencer, 2001, Mansfield 1991 and 1998, Rosenberg and Nelson, 1994).

Adams, Chiang and Starkey (2001) find evidence that industry-university cooperative research centers are conducive to industry-university technology transfer.

The forms of university-industry relations may include, for instance, informal information sharing among research partners, one-on-one research ventures, or research focused on solving a specific problem of firms (see also Hertzfeld, Link and Vonortas, 2005). According to Arundel and Geuna (2004), Europe's largest firms mainly assess public research output by hiring trained scientists and engineers, through informal personal contacts, by contracting research out to public research organizations, and through joint research projects.[8] Furthermore, firms that have downsized their research and development facilities may benefit from linkages with universities, as well (Adams, Chiang and Starkey, 2001). Especially small ventures only obtain access to R&D inputs via cooperation with research institutions (Audretsch and Feldman 2004). Research partnerships with universities expand and complement the absorptive capacity of the cooperative firm (Scott, 2003). Therefore, university-industry research partnerships are transmission channels for both small and large firms to generate, receive, apply and commercialize knowledge.

Based upon these assumptions, the commercialization of knowledge is facilitated by research and development activities of firms and research institutions (the knowledge stock and absorptive capacity), entrepreneurship, and university-industry relations. This paper puts forward that the contribution of entrepreneurial activity and university-industry partnerships may spur economic growth and explain why regions post different growth rates. Furthermore, regional differences in economic growth may also be caused by agglomeration externalities i.e. the concentration of firms in same or related industries,

[8] See also Cohen, Nelson and Walsh (2002b) for an analysis of the influence of public research on industrial R&D. They found that the dominant channel of knowledge transfer is publications and reports, followed by informal exchange, public meetings or conferences, and consulting. Private businesses rated contract research and cooperative ventures and patens as well as hiring graduates as moderately important.

universities and research facilities, and (qualified) labor provide a pool of technical knowledge (Feldman and Florida, 1994; Acs and Varga, 2004).[9]

3 Data and Methodology

The purpose of the paper is to develop a regional model of economic growth for West German districts between 1992 and 2000 (326 districts) and empirically test the hypothesis if entrepreneurship and university-industry relations foster growth. Economic growth is measured in two ways, firstly by the growth rate of economic output and secondly by the growth rate of total factor productivity. The analysis is restricted to West Germany because East Germany can be regarded as a special case with very specific conditions not comparable to the West in the 1990s (see for instance Fritsch, 2004). The empirical estimations employ panel regressions with fixed effects and control for spatial autocorrelation.

The starting point is a neoclassical production function, $Y(t) = A(t)\, K^{\alpha} L^{\beta}$, where economic output is determined by physical capital *K*, labor *L* and the level of technology *A(t)* (also called total factor productivity). The growth rate of the aggregate output is broken down into the contributions from the growth of capital and labor. The growth rate of aggregate output can be written as $\dot{Y}/Y = \dot{A}/A + \alpha(t)\cdot\left(\dot{K}/K\right) + [1-\alpha(t)]\cdot\left(\dot{L}/L\right)$.[10] Regional aggregate output *Y* is measured by regional gross value added of all industries (at constant 1995 prices). The physical capital stock *K* is calculated from gross fixed capital formation (investments, at constant 1995 prices) following the perpetual inventory method (for details see, Mueller, 2004). The number of employees measures labor *L*. All data on regional gross value added and gross fixed capital formation (investments) are from various publications of the federal statistical office and statistical offices of each state (*Bundesländer*).[11] The gross fixed capital formation of some districts

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[9] See also Glaeser, Kallal, Scheinkaman and Shleifer (1992) and Jaffe, Trajtenberg and Henderson (1993) and others.

[10] See Barro and Sala-i-Martin (1995) for an overview of growth accounting.

[11] Data on gross fixed capital formation (investment) are annually published by each statistical office of the German Federal States (series E I 6). Data on regional gross value added are published by the working group of the Statistical Offices of the German Federal States, Volkswirtschaftliche Gesamtrechnung der Laender (VGR d L) every other year between 1976 and 1990 and annually since 1992.

is not reported due to confidentiality; therefore, they had to be excluded from the data set. The number of employees in each region is from the establishment file of the German Social Insurance Statistics. In Germany all public and private employees must be reported to the Federal Employment Office for enrollment in the social insurance system.[12]

The empirical modeling framework develops a regional model of economic growth.[13] In order to test the hypothesis if economic growth depends on the region's absorptive capacity, entrepreneurship, and university-industry relations the following model is developed. Entrepreneurship and university-industry relations shall test the permeability of the knowledge filter and analyze if they spur economic growth by functioning as possible transmission channels for the flow of knowledge.

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\begin{aligned}
(1)\quad \ln\left(Y(t)/Y(t_0)\right) = \quad & \alpha_1 \ln\left(K(t)/K(t_0)\right) + \alpha_2 \ln\left(L(t)/L(t_0)\right) \\
& + \alpha_3\left(RDI_{i,t}\right) + \alpha_4\left(RDP_{i,t}\right) + \alpha_5\left(E_{i,t}\right) + \alpha_6\left(UI_{i,t}\right) \\
& + \alpha_7\left(AGG_{i,t}\right) + \varepsilon_{i,t}
\end{aligned}
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In equation (1), in addition to the growth rate of physical capital and labor, regional economic growth is affected by research and development activities in private enterprises (RDI) and the generation of knowledge in universities (RDP), entrepreneurship activity (E), and university-industry relations (UI), as well as by agglomeration externalities (AGG). The subscript *i* refers to the respective West German districts, t runs from 1992 to 2000 and t_0 is the initial value in 1992. The regional knowledge stock and the region's absorptive capacity are measured by R&D activities in the private sector and in universities. While the share of employees devoted to R&D in the private sector measures R&D in private industries, R&D in universities is measured by the number of researchers at universities per overall employees in the respective district. Regional entrepreneurship activity is measured by the region's start-up rate; namely the

[12] Civil servants, army personnel, self-employed etc. are not obliged to contribute to the social insurance system and are, therefore, not listed (for details see Fritsch and Brixy, 2004).

[13] See also Audretsch and Keilbach (2004) for an economic growth model including entrepreneurship on the regional level.

number of new businesses formed per 1,000 employees in the respective district. The regional level of university-industry relations is measured by the amount of grants given from firms in the private sector to universities. Although the data provides no information on the location of the respective private firms, other studies have shown that the industry-university cooperation in Germany tends to be rather concentrated in the university's vicinity (Fritsch and Schwirten, 1999). The empirical model also accounts for university research funded by the German Science Foundation. The goal of this foundation is to promote scientific excellence, and only a small range of scientists are funded each year. Both indicators of external research funds can be regarded as an indicator for the quality of research performed at the universities in the respective regions.

The data on new businesses and the business stock are provided by the establishment file of the German Social Insurance Statistics (for details see, Fritsch and Brixy, 2004). All establishments with at least one employee who is subject to obligatory social insurance are listed in this file. Therefore, firms consisting only of owners are not included. The information is available on the regional level (districts) and for a relatively long time period, between 1983 and 2002, for West Germany. The data regarding the number of employees engaged in research and development in private businesses are also from the German Social Insurance Statistics. The database comprises information on education and occupation of the listed employees. Information exists for the years from 1987 to 2000. Employees are counted as R&D employees if they obtained a university degree in natural science or engineering. The data on the number of researchers at universities are from the Federal Statistical Office. All other data about academia-like researchers, scientists, and financial resources (grants, revenues, and expenses) are from the Federal Statistical Office as well. The information is available for each university and has been aggregated at the district level.

Table1: Descriptive Statistics

	Mean	Std. dev.	Min.	Max.
Number of employees in R&D in private industries	1,505.03	2,850.50	31	33,765
Share of employees in R&D in private industries to all employees (%)	2.10	1.45	0.32	16.03
Number of researcher and scientists in universities	526.29	1324.62	0	11,684
Share of researcher and scientists in universities to all employees (%)	0.67	1.53	0	12.49
Number of start-ups	432.12	458.46	62	6,134
Start-up rate (start-ups per 1,000 employees)	8.60	2.65	1.92	20.64
Grant from firms in private industries (thousand Euro, constant 1995 prices)	1,588.46	6,326.98	0	101,558
Grant from German Science Foundation (thousand Euro, constant 1995 prices)	1,867.80	6,004.24	0	68,755
Population density (inhabitants per square kilometer)	565.95	696.22	41.18	4037.37

Note: All data are on the regional level (districts) and within the time period of 1992-2000.

The descriptive statistics of all variables are presented in Table 1. The number of employees devoted to research and development in private industries range from 31 to 33,765 employees per district; the share ranges from below 1 percent to about 16 percent. The skewness of the distribution of researchers and scientists at universities is quite obvious, the number ranges from zero to 11,684 per district and the share from 0 percent to 12.49 percent. The district with the fewest start-ups has 62 new ventures; the maximum for new businesses is 6,134. The start-up rate ranges from 1.92 to 20.64; on average there are 8 new businesses per 1,000 employees. At the district level, differences regarding grants from private firms to universities are highly distinct; it ranges from zero Euros to 101,558,000 Euros (in constant 1995 prices). The distribution is heavily skewed, while on average the district received 1,588,460 Euros, about 50 percent of the districts did not obtain grants over the years. The reason for the heterogeneity is that many universities in Germany are located in cities, and core cities often correspond with a district. Hence, those districts that do not have a university but are around a core city have not received any grants.[14] Nevertheless, districts adjacent to university cities may

[14] One could argue that universities of applied science (*Fachhochschule*) are located in both moderately congested areas and rural areas and will absorb this imbalance, but universities of applied science do not have a high amount of grants from firms in private industries.

benefit from research activities of the universities due to their proximity. The total amount of grants from private businesses to universities increased from 389 million Euros in 1992 to 651 million Euros in 2000 in West Germany. The large increase indicates that technology transfer from universities increased over the 1990s. University funding from the German Science Foundation ranges from zero Euros to a maximum of 68,755 Euros. The average amount of these funds (1,867.80 Euros) is slightly higher than the average amount of grants from private firms. The descriptive statistics of the variable population density shows strong differences as well; it ranges from 42 to 4,038 inhabitants per square kilometers.

4 Entrepreneurship and University-Industry Relations: Empirical Evidence of the Knowledge Filter

If entrepreneurship and university-industry relations penetrate the knowledge filter, knowledge flows are facilitated and a positive impact on economic growth can be expected. A statistically positive relationship between economic growth and the growth rate of labor and capital is always found (Table 2). While the impact of labor is always highly significant, the relationship between capital and economic growth is only weakly significant. The region’s absorptive capacity, the region’s knowledge stock, is measured by the share of R&D employees in private industries and the share of researchers and scientists at the universities. The estimates imply a strong positive impact of research and development in private industries on regional economic growth, the higher the level of absorptive capacity in the region the higher the economic growth will be (model II-IV).

Table 2: Impact of entrepreneurship and university-industry relations on regional economic growth

	Regional economic growth			
	(I)	(II)	(III)	(IV)
Growth rate capital	0.025*	0.018	0.025*	0.021
	(2.23)	(1.48)	(2.08)	(1.73)
Growth rate labor	0.470**	0.460**	0.529**	0.506**
	(25.62)	(22.10)	(25.51)	(23.66)
R&D in private industries	–	0.060**	0.055**	0.054**
		(14.52)	(13.49)	(13.27)
R&D in universities	–	0.005	0.003	0.004
		(1.02)	(0.65)	(0.91)
Start-up rate	–	–	0.012**	0.012**
			(18.41)	(18.47)
University-industry relations (ln)	–	–	0.002**	0.002**
			(3.49)	(3.65)
Research funds from German Science Foundation (ln)	–	–	0.001	0.001
			(1.26)	(1.56)
Agglomeration	–	–	–	0.0003**
				(3.94)
Constant	0.038**	-0.089**	-0.187**	-0.338**
	(37.90)	(10.03)	(20.56)	(8.65)
Spatial autocorrelation (residuals)	0.815**	0.762**	0.645**	0.647**
	(50.60)	(28.10)	(21.30)	(21.42)
R^2-adj. (within)	0.5453	0.4776	0.4691	0.4991
R^2-adj. (overall)	0.4673	0.0713	0.1214	0.0035
F	1018.85	440.53	296.10	266.21
Observations	2728	2728	2728	2728

Note: * significant at 5%-level, ** significant at 1%-level, t-values in parentheses, panel regressions with fixed effects.

The relationship between research conducted at universities and economic growth is positive but not significant. One reason could be that knowledge generated in universities still needs to be applied, and its commercialization depends on additional knowledge transfer channels. Nevertheless, researchers at private industries and universities seem to be a necessary condition for economic growth. The two proposed transmission channels for knowledge spillovers enter the regression in the predicted positive way (model III). While entrepreneurs exploit knowledge by setting up a new firm, they penetrate the knowledge filter and stimulate economic growth. University-industry relations also confirm their ability to penetrate the knowledge filter, hence spurring growth. The results suggest that knowledge generated in universities, which is usually abundant but underexploited, can be transferred to be capitalized through research partnerships.

Funds granted by the German Science Foundation do not prove to have a significant impact on economic growth. Nevertheless, this variable controls for excellent research, which is an important part of the regional knowledge stock. The region's population density controls for agglomeration externalities (Table 2, model IV). Regions benefit from a higher pool of inhabitants, employees, firms, or students as well as from the proximity to firms, universities, and research institutions. Firms then have better access to their demanded labor force, and the interchange of employees between firms is easier due to spatial proximity. Businesses might cluster in a specific region; hence, industry-specific knowledge is more accessible and might diffuse easier. The results suggest that agglomerated regions have higher growth rates of economic output.

Table 3: Impact of entrepreneurship and university-industry relations on technological progress

	Regional technological progress		
	(I)	(II)	(III)
R&D in private industries	0.057**	0.053**	0.051**
	(14.10)	(13.00)	(12.69)
R&D in universities	0.002	-0.003	-0.000
	(0.33)	(0.55)	(0.01)
Start-up rate	–	0.011**	0.012**
		(17.44)	(17.79)
University-industry relations (ln)	–	0.0012**	0.0014**
		(2.71)	(3.05)
Research funds from German Science Foundation (ln)	–	0.0006	0.0008
		(1.18)	(1.60)
Agglomeration	–	–	0.0003**
			(5.25)
Constant	-0.120**	-0.213**	-0.409**
	(13.65)	(23.32)	(11.77)
Spatial autocorrelation (residuals)	0.745**	0.620**	0.626**
	(27.65)	(20.62)	(20.81)
R^2-adj. (within)	0.4117	0.4268	0.4328
R^2-adj. (overall)	0.0486	0.0648	0.0047
F	562.42	298.78	262.33
Observations	2728	2728	2728

Note: * significant at 5%-level, ** significant at 1%-level, t-values in parentheses, panel regressions with fixed effects.

Another way of growth accounting is to estimate technological progress, this can be done by subtracting from the growth rate of economic output that part of growth rate that can be accounted for by the growth rate of the inputs capital and labor.[15] The residual is the rate of technological progress. This allows analyzing the impact of entrepreneurship activity and university-industry relations on technological progress (Table 3). The results resemble those of Table 2. Those regions where the absorptive capacity or the knowledge stock is higher also experience a higher technological progress (model I). The results of all models show a strong significant relationship between research and development activities in private industries and technological progress. R&D in private firms is the principal component of the regional knowledge stock. Corresponding to the results of Table 2, the impact of research and development at universities on technological progress is not significant. The results for model II and III show that both regional start-up rates and university-industry relations stimulate technological progress. Knowledge transfer may be fostered by the setting-up of a new firm and research partnerships. The coefficient of university funds provided by the German Science Foundation is positive but insignificant, indicating no direct relationship between these fund and technological progress. Model III reports an advantage of agglomerated regions regarding technological progress (akin to model IV, Table 2).

5 Conclusion

This paper addresses an important research question – the transfer and capitalization of knowledge by new firm formation and universities-industry relations and their impact on economic growth. Additionally, the findings suggest that a well developed regional knowledge stock is a crucial determinant of economic growth. New knowledge needs to be generated at incumbent firms and at universities before it can be exploited, and firms need to have the ability to apply and assimilate knowledge. Furthermore, regions with higher new firm formation activity and university-industry research partnerships experience higher growth rates and technological progress. Consequently, it may be concluded that the proposed knowledge transmission channels amplify the permeability of the knowledge filter and facilitate knowledge flows.

[15] See Barro and Sala-i-Martin (1995) for an overview of growth accounting.

The essential questions for public policy are first, how university-industry research partnerships come about and what conditions are necessary for their success, and secondly, how can the set-up of a new firm be encouraged. The German government and the European Commission have introduced various instruments to foster research partnerships and cooperation between universities, research institutes, and private businesses. In order to receive subsidies from public support programs, universities or firms need to collaborate with each other. For instance, the goal of the German funding initiative BioRegions attempted to create economic areas in which scientific and economic potential are brought together to foster scientific research and the capitalization of the generated knowledge in the field of biotechnology. Other programs have supported the establishment of science parks close to universities or encouraged young researchers and scientists to start their own venture.

Public policy programs regarding entrepreneurship may start by stimulating entrepreneurial awareness and developing entrepreneurial skills. Many universities have already incorporated entrepreneurship education into the curriculum, or they provide counseling to potential business founders. Since new ventures are also subject to financial constraints, public policy programs may provide access to loan financing, i.e. the state may act as guarantor of bank loans (see also Storey, 2003). In Germany, the KFW SME Bank offers support with loans, mezzanine financing, and equity capital to young firm owners and entrepreneurs.

Hall, Link and Scott (2001) found that intellectual property issues between firms and universities exist and that these issues can almost be an invincibly barrier for research partnerships, in particular, if the results of the joint research are hardly appropriable. Hertzfeld, Link and Vonortas (2005) concluded that the protection of intellectual property is an important issue but not the premier restraint. However, they also found that negotiations on intellectual property between firms and universities have recently created additional tension and difficulties. Therefore, government needs to install an appropriate legal infrastructure to facilitate partnerships with universities.

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