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University Education, Public Research and Employment Growth in Regions – An Empirical Study of Germany

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Abstract:

Universities and research institutes are seen as important drivers of the regional economy. Their impact on regional entrepreneurial and innovation activity is well documented. On the other hand, their influence on regional employment growth is less researched. This paper provides an extensive empirical analysis of the relationship between the education of university graduates and employees in research institutes and the growth of employment in a region. The analysis is done for nine industries separately. We find that university graduates have a significant influence on employment growth in several industries, while an influence of public research institutes is found only for a few industries. For most control variables the findings differ between manufacturing and service industries. Such a clear difference between the two types of industries is not found for university graduates and public research institutes.

Keywords: Universities, Research Institutes, Regional Employment Growth.

JEL Classifications: H52, I2, J20

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1 Introduction

The scientific literature as well as the public opinion usually associates universities and research institutes with economic growth. This becomes most obvious in the literature on endogenous growth theories (e.g. ROMER 1994) explaining growth on the basis of human capital and knowledge accumulation. This suggests that more universities and research institutes in a region should imply a higher growth rate of the regional economy.

Local effects of universities and research institutes are extensively studied in the literature. Especially the positive effect of public research on innovation activities of nearby firms (e.g. JAFFE 1989; FELDMAN U. FLORIDA 1994; ANSELIN ET AL. 1997; FRITSCH U. SLAVTCHEV 2007) and the importance of universities and research institutes as sources of spin-offs (e.g. COHEN ET AL. 2002; ANSELIN ET AL. 1997; KIRCHHOFF ET AL. 2007) are confirmed by empirical studies. The effects of universities and research institutes on the growth of employment are less frequently studied.

This paper tries to fill this gap partly. Using data on German labour market areas[1], our study aims to determine whether the number of university graduates and the number of employees in public research institutes in certain fields influence the growth of employment in the respective industries. We address this question from an empirical perspective. To this end, empirical data on the number of graduates in diverse university subjects in all German labour market areas as well as the number of employees in various subjects in research institutes of the four main German research societies from 1999 to 2006 is used. Together with a number of control variables, such as GDP, population density and high-school education, this data is used to explain employment growth in the years 1999 to 2007. It is assumed that different industries are influenced by different university subjects and different research topics. Hence, the analysis is conducted on nine industries (mainly on a 2-digit level) separately. Our study reveals significant effects of university graduates and/or public research on employment growth for most of the studied industries. However, these effects vary strongly between industries.

The paper is organized as follows. In Section 2 the theoretical background on the impact of university graduates and public research is discussed. Section 3 explains the used data, the regression model, and the method applied. The results are described and discussed in Section 4. Section 5 concludes.

[1] Labour market areas as defined by the German Institute for Labour (IAB)

2 Theoretical Background

The impact of public research and university education has been discussed among scientists and practitioners for a long time. A large number of empirical studies does focus on different aspects and analyses interrelations between the scientific inputs and economic outputs. Among the first theories analysing economic growth on the basis of human capital creation and the accumulation of knowledge have been the endogenous growth theories (see ROMER 1994). As a reaction to neoclassical approaches, explaining technological processes by exogenous forces, endogenous growth theories deal with innovations and long-term economic growth within the model. Human capital is seen as generating positive effects for the economic development. Thus, investments in education and research should lead to an increasing stock of human capital which causes a higher productivity (see MARTIN U. SUNLEY 1998). Knowledge is treated as a positive externality that spills over between different economic actors and influences the scale of economic activity (see DOERING U. SCHNELLENBACH 2006). The diffusion of knowledge and spill over processes are sensitive to geographic distance, but they are not completely bounded in space. Therefore, public research is said to have an impact primarily within the particular region and a smaller impact on locations farer away (ANSELIN ET AL. 1997).

Nevertheless, the relationship between high investments in education and research and a high economic output is not always seen as causal and thus needs to be tested empirically (see MARTIN U. SUNLEY 1998).

2.1 Roles of Universities and Research Institutions

Universities and research institutions have different roles in the scientific community but also overlap regarding certain aspects. In general, the two main tasks of universities are education and research. Normally, these two aspects are closely connected as graduates leave university with up-to-date knowledge and skills. Research at universities influences the teaching portfolio and student assistants may get deeper knowledge when working in laboratories and research. When they start working, this up-to-date knowledge spills over from the university into the private sector (see SALTER U. MARTIN 2001; BRESCHI U. LISSONI 2001). Thus, research at universities is discussed in our study without being explicitly examined since we include university graduates as a variable in the study.

The role of research institutes is different. Their main target is research; the educational part is less important as only a small number of researchers leave the institutes to be employed somewhere else. Thus, we analyse mainly the impact of research when using research institutes as an explaining variable in our study. Furthermore, spin-offs that originate from research institutes and universities may have an impact on the employment growth in a region (see KIRCHHOFF ET AL. 2007).

2.2 Spatial Impact of Graduates and Research

It is well known that university students and graduates are among the most mobile groups of society. After finishing their education, students are quite willing to leave a region if they need to for employment (see MOHR 2002). The location of a university thus seems to be unimportant for the impact of graduates on the labour market. On the other hand, economically successful regions have a great potential to keep highly qualified graduates and therefore generate skilled human capital. Hence, it is very likely that regions well endowed with excellent universities end up with more and better qualified university graduates (see HUFFMAN U. QUIGLEY 2002; BRESCHI U. LISSONI 2001). The local labour market with its intra-regional formal and informal contacts plays an enormous role for the diffusion of knowledge. Highly educated graduates transfer their up-to-date knowledge from university to their employer and thus influence the innovativeness of the employing firms. However, this does not necessarily need to happen within the region where the university is located (see SALTER U. MARTIN 2001).

Similarly, there are contradictory arguments about the spatial spread of the impact of research institutes. On the one hand, spill over processes are geographically bounded: The region where a research institute is located does profit from knowledge spill overs which are transferred via labour markets and other markets for specialized inputs (see BRESCHI U. LISSONI 2001; ACS ET AL. 2002). On the other hand, BLIND U. GRUPP (1999, 452) point out that "universities and other research labs transfer knowledge more effectively to larger companies with no regional priority". This applies mainly for codified knowledge while a lot of other processes still are dependent on geographical proximity (see DEL BARRIO-CASTRO U. GARCÌA-QUEVEDO 2005). Hence, there is more evidence suggesting a regional focus of the impact of research institutes (see ARUNDEL U. GEUNA 2004).

To sum up, the theoretical considerations above implicate the following picture: University education and graduates do not have a strong regional impact whereas the effect of research conducted in local institutes mainly seems to be found in the region.

2.3 Impact on Regional Employment

Most studies on the economic impact of universities on regional development do not focus the universities' impact on regional employment growth.

However, employment and markets which develop due to innovative activities are of public interest and serve as economic aim and for the evaluation of policy action (see ACS ET AL. 2002). A main aim of the Lisboan strategy of the European Council is to foster employment growth by raising the investments in education and research and thus supporting innovation (see COUNCIL OF THE EUROPEAN UNION 2003).

But the picture regarding the impacts of process and product innovations is mixed. Primarily, the effects of process innovations are negative, on average, as new processes often need less manpower. Secondary effects may be positive if saved capital is invested in new developments or products. Vice versa, product innovations first may have a positive impact if new products are introduced and production is expanded but later on old products may be substituted (see GRUPP 1997). Generally, the development of employment is better in innovative regions and firms (see MEYER-KRAHMER 1999).

Regarding regional employment growth it is important to mention that endless growth is not possible. Growth is limited by the potential of employees in a region, maybe also the available number of university graduates.

BRÄUNINGER ET AL. (2008) in a study on German administrative districts find that the number of highly educated employees determines the whole employment growth in a region. They test how regions in different scenarios develop with a certain supply of highly qualified workers and find that the higher the supply of highly qualified human capital in a region the better the regional employment growth. Furthermore, spin-offs from university lead to employment growth in the region (see KIRCHHOFF ET AL. 2007). The regional labour market is also likely to influence the education function of universities in some subjects (see BLIND U. GRUPP 1999).

Summing all up, highly qualified human capital seems to play a crucial role in regional employment growth. One of the questions we would like to answer with our empirical model is whether the high mobility of graduates blurs the regional impact.

3 Empirical Data and Methodology

In order to estimate the impact of university education and public research institutes on employment growth, we estimate a regression model on the basis of data for German labour market areas.

3.1 Regression Model and Approach

The variable we intend to explain is the change in employment in an industry and region. Let us denote the employment in an industry i in a region r at time t by $e_{i,r,t}$. The change, $e_{i,r,t+1}$-$e_{i,r,t}$, is the dependent variable which has to be explained. However, a standard regression approach with this change as independent variable cannot be applied since residuals are not normally distributed. Instead the changes on logarithmic scale, $\log(e_{i,r,t+1})-\log(e_{i,r,t})$, follow a Subbotin distribution, similar to the growth of firms. Hence, the regression model is formulated for the change $\angle=\log(e_{i,r,t+1})-\log(e_{i,r,t})$. The probability density of each change to occur is given by the Subbotin distribution

$$p(\mathit{\Delta}) = \frac{1}{2 \cdot a \cdot b^{\frac{1}{b}} \cdot \Gamma\left(1+\frac{1}{b}\right)} \cdot \exp\left(-\frac{1}{b} \cdot \left|\frac{\mathit{\Delta}-\overline{\mathit{\Delta}}}{a}\right|^{b}\right) \tag{1}$$

where Γ stands for the gamma function and a and b are parameters that determine the statistical characteristics of the Subbotin distribution. a determines the spread of the distribution, i.e. the fluctuations that are not predicted by the independent variables, while b determines the exact shape of the distribution.

$\angle$ denotes the expected change. While the parameters, a and b, characterize the error term of the regression, we try to predict the value of $\angle$ by the independent variables. We could formulate $\angle$ as a linear function of the independent variables. However, this is not adequate because, for example, a higher number of university graduates does not imply a positive change of employment for all time. Theoretically we can rather argue that a certain number of employees requires a certain number of university graduates. If the number of graduates is below this number it might have a negative effect on employment growth. If it is above this number it might have a positive effect.

Several pre-tests have led to the conclusion that the following mathematical formulation for $\angle$ is most adequate:

$$\overline{\Delta} = \log\left(\sum_{j=1}^{n_v}\left(\alpha_{i,j} \cdot v_{j,r,t}\right) \cdot \prod_{j=1}^{n_w} w_{j,r,t}^{\beta_{i,j}}\right) - \log\left(e_{i,r,t}\right) \quad .(2)$$

In this equation, two kinds of independent variables are defined: v-variables and w-variables. We can interpret the value within the first log-function on the right-hand side of Equation (2) as the employment that is predicted or supported by the independent variables. Besides independent variables which enter this prediction additively ($a_{i,j}$ $v_{j,r,t}$), the v-variables, there are independent variables that enter this prediction multiplicatively ($w_{j,r,t}^{\beta_{ij}}$), the w-variables (for a similar distinction between additive and multiplicative factors see BRENNER U. BROEKEL 2009). For some variables there are clear arguments about whether they should enter as v-variable or w-variables. For other variables we simply checked empirically which way of inclusion makes the model most adequate. Table 1 presents all variables used and the way of their inclusion.

Variable	Description	Way of inclusion
EMPL	Number of employees in the region and industry	Additive
LQ	Location quotient of the industry (values below 0.001 are set to 0.001)	Multiplicative
DENS	Population density of the region divided by the average population density of Germany	Multiplicative
GDP	GDP per inhabitant in the region divided by the average GDP per inhabitant in Germany	Multiplicative
UNEMP	Unemployment rate in the region divided by the average unemployment rate in Germany	Multiplicative
SCHOOL	Share of population with a high-school degree divided by the share of such people in Germany	Multiplicative
POP	Number of inhabitants	Additive
EAST	Dummy that takes the value of 1.1 for regions in former East Germany and of 0.9 for regions in former West Germany	Multiplicative
STUD-..	Number of university graduates in a certain subject	Additive
RES-..	Number of employees in public research institutes in the region in a certain subject	Multiplicative, but with the mathematical form $(1+\beta_{ij}\cdot w_{j,r,t})$

Table 1 All factors included in the regression as independent variables

Concerning the number of university graduates and employees of the public research institutes we include only those in each regression that belong to certain scientific subjects. For each industry we define two or three subjects which might be relevant for that particular industry. The industries and the considered subjects are presented in Table 2. For each subject two independent variables are formed: one representing the number of university graduates [STUD-..] and one representing the number of employees in the public research institutes [RES-..].

Industry	Subjects for which university graduates and employees at public research institutes were selected as independent variables
Chemicals (Code 24 without 24.4)	Physics, chemistry
Pharmaceuticals (Code 24.4)	Pharmacy, biology, medical sciences
Machinery (Code 29)	Physics, engineering, mechanical engineering
Electrics & Electronics (Codes 31 and 32)	Physics, mechanical engineering, electrical engineering
Automotive (Code 34)	Mechanical engineering, electrical engineering, transportation engineering
Software (Code 72)	Mathematics, informatics, physics
Business consulting (Code 74.1)	Law, economics
Finance & Insurance (Codes 65-67)	Economics, mathematics
Media (Code 92)	Arts, design, media

Table 2 Industries studied and subjects for which university graduates and public research institutes are included as independent variables

The regressions are conducted numerically. A maximum likelihood approach is taken. To avoid multicollinearity, variables with significant correlation coefficients above 0.7 or below -0.7 are not included in the same model. Several models including different independent variables are estimated. The discussion of the results does focus on the model with the highest value of R^2. The detailed results for this model as well as the alternative models replacing one of the independent variables by another that cannot be included at the same time are presented in the Appendix.

3.2 Empirical Data

All analyses are conducted on the level of the 270 labour market areas for Germany which take into account the commuting of employees and therefore are the most adequate definition of region in order to assume that most above modelled effects happen within regions (see ECKEY ET AL. 2007). Nevertheless, there might be relationships between regions. Therefore, we test for spatial autocorrelation.

Our dependent variable is the change of the logarithm of employment. Data on the employment numbers in each industry and region are obtained from the German Institute for Labour[2] for the 31st of June for each year from 1999 to 2007. Hence, the regressions are based for all industries on the values in 270 regions and 8 years from 1999 to 2006.

As presented above in Table 1, we include a number of independent variables as control variables. Most of these variables are obtained from the regional data sets INKAR that are delivered by the Federal Institute for Research on Building, Urban Affairs and Spatial Development. This holds for the data on population density [DENS], the GDP per inhabitant [GDP], the unemployment rate [UNEMP], the share of inhabitants with a high-school degree [SCHOOL] and the number of inhabitants [POP]. The location quotient [LQ] is directly calculated from the employment data.

Data on the number of university graduates [STUD-..] is obtained from the German Statistical Office. We include all kinds of universities, i.e. universities as well as technical and administrative colleges[3]. All data described above is available for each year from 1999 to 2006.

Data on the public research institutes has been collected by us. In this data base we included the four large research organizations in Germany: the Helmholtz Association, the Max Planck Society, the Fraunhofer Society and the Leibniz Association. We identified all institutes that belong to these organizations and took the number of employees from their reports for as many years as possible.[4] In order to assign the research institutes to the different subjects we would like to discuss, we asked all institutes to do this on their own. Around 75% of the addressed institutes did answer this request and assigned their research activities to scientific subjects. These institutes are considered in the analysis. If

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2 IAB

3 Fachhochschulen

4 If a value was not available for a certain year the value was taken from the most nearest year for which a value was available.

an institute is conduction research in several subjects they provided us with respective shares. In such cases, the total number of employees is distributed among the different subjects according to the announced shares.

4 Results

In order to examine whether different industries show different dependencies we include very differing industries in the study. Indeed, we find clear differences between industries. This holds for the control variables as well as for the impact of graduates and employees in public research institutes. Table 3 and Table 4 show an overview of all significant results. Signs without parentheses are significant in the best fitting regressions[5]. If there is a zero in parentheses behind these signs, this significance vanishes in alternative models and is not stable. A contrary sign in parentheses indicates that this correlation turns to the other side in alternative models. Signs in parentheses stand for significant findings in the alternative models only.

Variable	Industry				
	Chemicals	Pharma-ceuticals	Machinery	Electrics & Elec-tronics	Automotive
EMPL	0	+	+	0	0
POP	(+)	+	(+)		
LQ	(-)	+			-
DENS	-		-		-
GDP	-	-	0	-	+ (-)
UNEMP	-	-		0	(-)
EAST		(-)	+	(+)	+
SCHOOL		0			(+)
STUD-..	Chemistry		General eng.	Mech. eng. (physics, electr. eng.)	
RES-..			(physics)		Electr. eng. (0), trans. eng.

Table 3 Significant impacts of the independent variables on manufacturing employment growth

5 The detailed results obtained by the different models are presented in the Appendix.

Variable	Industry			
	Software	Business consulting	Finance & Insurance	Media
EMPL	(+)		(+)	+
POP	+	+	+	
LQ	+	+	+	(+)
DENS		+	-	
GDP	+	+		
UNEMP			-	
EAST	0	+	(-)	
SCHOOL	(+)	(+)		
STUD-..	Math (0) (informatics, physics)			
RES-..	Physics (0), (math)			

Table 4 Significant impacts of the independent variables on employment growth in services

4.1 Control Variables

The employment [EMPL] in the same industry is especially significant in manufacturing industries. In other words, the existing employment enforces growth in the same industry. For service industries this influence is less striking. In return, the location quotient [LQ] is mainly positive for the service industries. Hence, the overall number of employees plays a bigger role for the manufacturing industries whereas the specialisation is more important for employment growth in the service industries. This may be seen as a hint on the functioning of cluster dynamics in these industries.

Also the population [POP] mainly shows a positive effect for services industries. Only the media industry acts like most of the manufacturing industries. The population density [DENS] has in most cases negative or no impact on employment growth. Only the business consulting industry is positively affected by a high population density. ´Older` manufacturing industries tend to leave agglomerations since they suffer more from agglomeration disadvantages like higher costs for industrial estates, labour and taxes than service industries (see NERLINGER 1998).

Unemployment [UMEMP] has a negative impact on most manufacturing industries while it is less important for service industries. This implies that especially for manufacturing industries unemployment leads to a further decline in employment, i.e. manufacturing industries suffer in regions with high unemployment due to economic problems.

The GDP per inhabitant [GDP], the east-west dummy [EAST] and the share of the population with a high school degree [SCHOOL] do not show robust results with a clear trend.

4.2 Impact of Graduates and Public Research

For most of the control variables it was possible to distinguish between manufacturing and service industries. Hence, we were able to show different patterns and paradigms of the distinct industry types. The influence of university graduates and employees at research institutes do not follow such patterns but differ between industries.

Let us start with the impact of graduates. In the case of the chemical industry we find a significant impact of graduates in Chemistry and in the case of the machinery industry a significant impact of graduates in General Engineering. No impacts are found for the graduates in the case of the pharmaceuticals and automotive industries.

Interestingly, graduates in Mechanical Engineering have a significant influence on employment growth in the electrics & electronics industry whereas the influence of graduates in Electrical Engineering is only significant in alternative models. However, the number of these kinds of graduates is highly correlated (correlation coefficient of 0.924) and the model including graduates in Mechanical Engineering is only slightly better fitting. The same holds for graduates in Physics who also show up significantly in alternative models. Hence, graduates in Mechanical Engineering predict employment growth best, but all three kinds of graduates might contribute.

Of all studied service industries we find a significant impact of university graduates only for the software industry. Here we have a similar phenomenon as in the case of the electrics & electronics industry. Graduates in Maths, Informatics and Physics are highly correlated so that they cannot be included together in the model. An inclusion of Maths graduates leads to the best fitting, but graduates in

Informatics and Physics have also significant impacts if they are included. Hence, all three kinds of graduates might contribute.

Students are very mobile when leaving university and thus may leave the region where the university is located. Nevertheless, according to our findings employment growth in many industries is influenced by the number of graduates educated in that specific region. Hence, higher numbers of students lead, at least in some industries, to higher employment. This seems to hold for manufacturing industries more frequently than for service industries but the discussion of five and four industries of these types is not sufficient to generalise this finding.

The influence of employees in research institutes shows somehow a different picture. We only find a significant impact for two industries in the best fitting model: the business consulting and the automotive industry. Employment growth in the business consulting industry is significantly influenced by employees in Law research institutes. In the automotive industry, we find a significant influence of employees of research institutes in electrical and transportation engineering. In addition, in alternative models the machinery industry shows significant influences of employees in institutes with a focus on physics. Employees in mathematical research institutes also have a significant influence on the software industry, but only in alternative models.

Altogether, we only find some influences of employees in research institutes. The theoretical arguments above imply a much stronger impact of public research on employment growth. Especially the knowledge intensive industries of pharmaceuticals and electronics are usually assumed to benefit strongly from nearby located research institutes. With respect to regional employment growth we are not able to support this claim.

However, two aspects have to be mentioned that should be considered in the interpretation of our results. First, we included in total 168 research institutes. This means that only a few regions have a research institute engaged in each studied subject. Significant results might therefore be rare also interdependencies exist. Second, university graduates are correlated with the respective research done at universities. Hence, the findings for the number of graduates might indicate an impact of the graduates as well as an impact of public research done at universities.

5 Conclusion

In this paper we empirically analysed the role of university graduates and employees in research institutes for regional employment growth in different industries. Until now, mainly the impact on firm's innovativeness and spin-offs have been explored (e.g. COHEN ET AL. 2002; FELDMAN U. FLORIDA 1994; ANSELIN ET AL. 1997) while the impacts on regional employment growth are less frequentl in the focus of interest. For nine different industries we tested whether the number of graduates in a certain university subject determines the regional employment growth. The same was done for the number of employees in research institutes which we assigned to university subjects. Besides, we controlled for different influences like the GDP, the population density, and the location quotient of the employment, the unemployment and the share of population with a high school degree.

We found for both variables, university education and research institutes, effects on local employment growth. However, the effects differ strongly between industries. For four industries we did not find any significant impact for both, university education and research institutes. In the case of the financial & insurance, business consulting and media industry this is not much of a surprise. In the case of pharmaceuticals it could have been expected that university education and public research play a stronger role. For other industries at least one of the variables discussed, university graduates or research institutes of some subjects, does play a significant role. We do not find much difference between the impact of university graduates and public research institutes. Hence, our theoretical prediction that the effect of research institutes should be more regionally bound, because university graduates are very mobile, is not confirmed. Both play a role for employment growth within a region, which supports the general assumption that universities and public research institutes can foster regional economic growth. However, our study also shows that the subject of university education as well as public research is important.

This empirical study has a number of shortcomings, which sets the agenda for further research. The results for the Moran's I show that in quite some industries spatial autocorrelations play an important role. Hence, these industries should be analysed including spatial relations between neighbouring regions. It would be even more interesting to conduct such an analysis with data with a better spatial resolution. Therefore, this study should be seen as a first step.

References

ACS, Z., FITZROY, F. and I. SMITH 2002: High-technology Employment and R&D in Cities: Heterogeneity vs. Specialization. In: The Annals of Regional Science, 36, p. 373-386.

ANSELIN, L., VARGA, A. and Z. ACS 1997: Local Geographic Spillovers between University Research and High Technology Innovations. In: Journal of Urban Economics, 42, p. 422-448.

ARUNDEL, A. and A. GEUNA 2004: Proximity and the use of public science by innovative European firms. In: Economics of Innovation & New Technology, 13, p. 559-580.

BLIND, K. and H. GRUPP 1999: Interdependencies between the Science and Technology Infrastructure and Innovation Activities in German Regions: Empirical Findings and Policy Consequences. In: Research Policy, 28, p. 451-468.

BRÄUNINGER, M., SCHLITTE, F., STILLER, S. and U. ZIERHAHN 2008: Deutschland 2018 - Die Arbeitsplätze der Zukunft. Regionen im Wettbewerb - Faktoren, Chancen und Szenarien. Hamburg.

BRENNER, T. and T. BROEKEL 2009: Methodological Issues in Measuring Innovation Performance of Spatial Units. Marburg. (=Working Papers on Innovation and Space, 01.09).

BRESCHI, S. and F. LISSONI 2001: Knowledge Spillovers and Local Innovation Systems: A Critical Survey. In: Industrial and Corporate Change, 10, p. 975-1005.

COHEN, W.M., NELSON, R.R. and J.P. WALSH 2002: Links and Impacts: The Influence of Public Research on Industrial R&D. In: Management Science, 48, p. 1-23.

COUNCIL OF THE EUROPEAN UNION 2003: Final Report on the European Action for Growth. Brussels.

DEL BARRIO-CASTRO, T. and J. GARCÍA-QUEVEDO 2005: Effects of University Research on the Geography of Innovation. In: Regional Studies, 39, p. 1217-1229.

DOERING, T. and J. SCHNELLENBACH 2006: What Do We Know about Geographical Knowledge Spillovers and Regional Growth? A Survey of the Literature. In: Regional Studies, 40, p. 375-395.

ECKEY, H., SCHWENGLER, B. and M. TÜRCK 2007: Vergleich von deutschen Arbeitsmarktregionen. Nürnberg. (=IAB Discussion Papers, 3/2007).

FELDMAN, M. and R. FLORIDA 1994: The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States. In: Annals of the Association of American Geographers, 84, p. 210-229.

FRITSCH, M. and V. SLAVTCHEV 2007: Universities and Innovation in Space. In: Industry and Innovation, 14, p. 201-218.

GRUPP, H. 1997: Technischer Wandel und Beschäftigung. In: SCHNABEL, H. (Ed.): Innovation und Arbeit. Tübingen, p. 1-24.

HUFFMAN, D. and J. QUIGLEY 2002: The Role of the University in Attracting High Tech Entrepreneurship: A Silicon Valley Tale. In: The Annals of Regional Science, 36, p. 403-419.

JAFFE, A. 1989: Real Effects of Academic Research. In: American Economic Review, 79, p. 957-970.

KIRCHHOFF, B., NEWBERT, S., HASAN, I. and C. ARMINGTON 2007: The Influence of University R&D Expenditures on New Business Formations and Employment Growth. In: Entrepreneurship Theory and Practice, 31, p. 543-559.

MARTIN, R. and P. SUNLEY 1998: Slow Convergence? The New Endogenous Growth Theory and Regional Development. In: Economic Geography, 74, p. 201-227.

MEYER-KRAHMER, F. 1999: Innovation als Beitrag zur Lösung von Beschäftigungsproblemen? In: Mitteilungen aus der Arbeitsmarkt- und Berufsforschung, 32, p. 402-415.

MOHR, H. 2002: Räumliche Mobilität von Hochschulabsolventen. In: BELLMANN, L. and J. VELLING (Ed.): Arbeitsmärkte für Hochqualifizierte. Nürnberg, p. 249-281.

NERLINGER, E. 1998: Standorte und Entwicklungen junger Unternehmen. Baden-Baden.

ROMER, P. 1994: The Origins of Endogenous Growth. In: Journal of Economic Perspectives, 8, p. 3-22.

SALTER, A. and B. MARTIN 2001: The Economic Benefits of Publicly Funded Basic Research: A Critical Review. In: Research Policy, 30, p. 509-532.

Appendix

In this appendix we present for all industries the best model and those alternative models that provide additional information about the significance of impacts. All other models are omitted her to save space and can be obtained from the authors. The tables show the regression coefficients and their significance (*** = 1%, ** = 5% and * = 10%). P-values are given in parentheses. Detailed descriptions of the variables are given in Table 1.

Variable	Best model	Alternative model 1
EMPLOYMENT	0.990*** (0)	
LOCATION QUOTIENT	0.00413 (0.053)	0.952*** (0.000)
DENSITY	0.00908 (0.248)	0.0210 (0.761)
GDP	0.0108 (0.181)	0.785*** (0.000)
UNEMPLOYMENT	0.00584 (0.191)	0.121* (0.021)
SCHOOL	-0.00819 (0.318)	0.0745 (0.385)
POPULATION		0.00100*** (0.000)
EAST		
STUDENTS-Arts	0 (0.961)	0.245 (0.335)
STUDENTS-Design	0.000762 (0.652)	0 (0.961)
STUDENTS-Media	0.0292 (0.052)	0.847 (0.063)
Cox-Snell pseudo R^2	0.451	0.299
Moran's I	-0.00708 (0.499)	0.0733*** (0)

Table 1 Best and alternative models in the media industry

Variable	Best model	Alternative model 1	Alternative model 2
EMPLOYMENT			0.521* (0.028)
LOCATION QUOTIENT	1.81*** (0.000)	2.93* (0.029)	0.301** (0.004)
DENSITY	-1.22** (0.001)	-3.81*** (0.000)	-0.351** (0.001)
GDP	0.352 (0.592)	0.178 (0.803)	-0.0613 (0.717)
UNEMPLOYMENT	-2.11*** (0)		-0.554*** (0)
SCHOOL	-0.801 (0.203)	-0.614 (0.589)	-0.273 (0.066)
POPULATION	0.000986* (0.012)	0.122* (0.048)	
EAST		-6.82*** (0.000)	
STUDENTS-Economics			0 (0.982)
RESEARCH-Economics	0 (0.976)	0 (0.980)	0 (0.982)
STUDENTS-Law	0 (0.976)	0 (0.980)	4.68e-06 (0.982)
RESEARCH -Law	7.78e-06 (0.978)	8.35e-08 (0.980)	1.66e-07 (0.982)
Cox-Snell pseudo R^2	0.829	0.818	0.828
Moran's I	0.217*** (0)	0.204*** (0)	0.207*** (0)

Table 2 Best and alternative models in the finance industry

Variable	Best model	Alternative model 1	Alternative model 2
EMPLOYMENT	0.0405* (0.020)	0.606* (0.038)	0.0402 (0.056)
LOCATION QUOTIENT	-0.01 (0.564)	-1.11*** (0.000)	0 (1)
DENSITY	-3.01*** (0.000)	-3.90** (0.002)	-2.98*** (0.000)
GDP	-4.71*** (0.000)	-6.88*** (0.000)	-4.79*** (0.001)
UNEMPLOYMENT	-2.95*** (0.000)	-4.31*** (0.000)	-2.94*** (0.000)
SCHOOL	0.597 (0.209)	0.01 (0.996)	0.571 (0.280)
POPULATION	0.00272 (0.060)		0.00269* (0.032)
EAST			
STUDENTS-Physics		38.0 (0.351)	
RESEARCH -Physics			7.65e-08 (0.250)
STUDENTS-Chemistry	28.6** (0.006)		28.0** (0.009)
RESEARCH -Chemistry	3.46e-07 (0.174)	6.48e-07 (0.371)	
Cox-Snell pseudo R^2	0.644	0.635	0.644
Moran's I	0.0389*** (0)	0.0735*** (0)	0.0385*** (0)

Table 3 Best and alternative models in the chemical industry

Variable	Best model	Alternative model 1	Alternative model 2
EMPLOYMENT	1.02*** (0)	1.02*** (0)	1.28*** (0)
LOCATION QUOTIENT	0.102*** (0.000)	0.101*** (0.000)	0.0810*** (0.000)
DENSITY	0.00350 (0.722)	0 (1)	-0.0108 (0.323)
GDP	-0.369*** (0.000)	-0.348*** (0.000)	-0.292*** (0.001)
UNEMPLOYMENT	-0.199*** (0.000)	-0.197*** (0.000)	
SCHOOL	0.118* (0.049)	0.119 (0.075)	0.171* (0.012)
POPULATION	3.56e-05*** (0)	3.55e-05*** (0)	3.67e-05*** (0)
EAST			-0.161** (0.001)
STUDENTS-Pharmacy			
RESEARCH-Pharmacy	0 (0.961)	1.22e-06 (0.621)	1.25e-07 (0.994)
STUDENTS-Biology			
RESEARCH - Biology		1.65e-21 (1)	
STUDENTS-Medical science	0.0949 (0.190)	0.019 (0.298)	0.0914 (0.615)
RESEARCH – Medical science	0 (0.927)		0 (0.733)
Cox-Snell pseudo R^2	0.818	0.818	0.814
Moran's I	-0.00203 (0.733)	-0.00277 (0.849)	0.00616* (0.046)

Table 4 Best and alternative models in the pharmaceutical industry

Variable	Best model	Alternative model 1	Alternative model 2	Alternative model 3	Alternative model 4
EMPLOYMENT	0.782*** (0.001)	1.36 (0.055)		6.95** (0.002)	1.38* (0.021)
LOCATION QUOTIENT	0.0476 (1)	-0.0827 (0.661)	0.253 (0.579)	0.349 (0.322)	-0.133 (0.538)
DENSITY	0.336 (0.120)	-0.0223 (1)	0.428 (0.506)	-0.359 (0.422)	-0.01 (0.985)
GDP	-3.341*** (0.000)	-9.268*** (0.000)	-26.8*** (0.000)	-9.23* (0.041)	-9.98*** (0.000)
UNEMPLOYMENT	-0.830*** (0.001)	-2.48** (0.008)	-7.40 (0.087)		-2.54* (0.014)
SCHOOL	0.445 (0.069)	4.00 (0.097)	5.26 (0.182)	2.04 (0.186)	3.88 (0.379)
POPULATION			0.00925(0.450)		
EAST				22.4* (0.031)	
STUDENTS-Physics		82.8* (0.046)		55.1 (0.995)	
RESEARCH -Physics	0 (1)	0 (0.999)	0 (0.985)	7.38e-07 (0.985)	1.48e-06 (1)
STUDENTS-Mechanical engineering	3.81*** (0.001)				
RESEARCH-Mechanical engineering	0 (1)	0 (0.999)	3.25e-05 (0.987)	9.53e-08 (0.979)	1.94e-07 (0.998)
STUDENTS-Electrical engineering					12.2* (0.020)
RESEARCH-Electrical engineering	6.59e-09 (1)	3.36e-10 (0.999)	1.28e-06 (0.985)	1.08e-09 (1)	9.65e-09 (0.998)
Cox-Snell pseudo R^2	0.515	0.499	0.493	0.497	0.502
Moran's I	0.0334*** (0)	0.0491*** (0)	0.0423*** (0)	0.223*** (0)	0.0593*** (0)

Table 5 Best and alternative models in the electrics industry

Variable	Best model 1	Best model 2	Alternative model 1	Alternative model 2
EMPLOYMENT	2.32***(0)	2.32***(0)	2.38(0.556)	1.15*(0.04)
LOCATION QUOTIENT	-0.170*** (0.000)	-0.170*** (0.000)	-0.186 (0.113)	-0.107* (0.025)
DENSITY	-1.58*** (5.96e-07)	-1.58*** (0.000)	-1.77*** (0.000)	-1.88*** (0.000)
GDP	2.05*** (0.000)	2.05*** (0.000)	2.21*** (0.000)	-0.428144* (0.0186223)
UNEMPLOYMENT				-0.463966* (0.0113216)
SCHOOL	-0.710 (0.182)	-0.710027 (0.197585)	-0.579 (0.187)	1.5872** (0.0015320)
POPULATION			0 (1)	8.2583e-05 (0.655365)
EAST	11.9*** (0)	11.9*** (0)	12.4*** (0)	
STUDENTS-Mechanical engineering		0.01 (0.711)		
RESEARCH-Mechanical engineering	0 (1)	0 (1)	0 (0.994)	0.000260 (0.699)
STUDENTS-Electrical engineering	0.01 (0.961)			
RESEARCH-Electrical engineering	0.00861* (0.027)	0.00861 (0.141)	0.0110 (0.114)	4.06e-05 (1)
STUDENTS-Transportation engineering	0.01 (0.961)			
RESEARCH-Transportation engineering	0.000522* (0.023)	0.000522* (0.025)	0.000592* (0.025)	0.000744* (0.026)
Cox-Snell pseudo R^2	0.946	0.946	0.946	0.941
Moran's I	0.211*** (0)	0.210*** (0)	0.186*** (0)	0.067*** (0)

Table 6: Best and alternative models in the automobile industry

Variable	Best model	Alternative model
EMPLOYMENT	1.19** (0.007)	0.926*** (0.001)
LOCATION QUOTIENT	0.0614 (0.493)	0.0236 (0.183)
DENSITY	-1.04*** (0)	-0.423*** (0)
GDP	1.23** (0.002)	0 (1)
UNEMPLOYMENT		-0.120 (0.167)
SCHOOL	-0.0604 (0.318)	0.00210 (1)
POPULATION	0.00110 (0.184)	0.000671* (0.048)
EAST	3.49** (0.001)	
STUDENTS-Physics		
RESEARCH -Physics	8.06e-09 (0.184)	1.05e-08* (0.029)
STUDENTS-General engineering	39.2* (0.041)	17.1** (0.007)
RESEARCH-General engineering	7.67e-08 (0.723)	9.29e-16 (1)
STUDENTS-Mechanical engineering		
RESEARCH-Mechanical engineering	3.26e-05 (1)	0.000402 (1)
Cox-Snell pseudo R^2	0.419	0.401
Moran's I	0.155*** (0)	0.0951*** (0)

Table 7 Best and alternative models in the machinery industry

Variable	Best model	Alternative model 1	Alternative model 2	Alternative model 3	Alternative model 4
EMPLOYMENT		69.7** (0.009)			
LOCATION QUOTIENT	0.908*** (0)	-4.60*** (0)	0.873*** (0)	-54.0*** (0)	0.899*** (0)
DENSITY	-0.0055 (1)	0.190 (0.991)	-0.0356 (0.509)	5.03 (0.685)	0.01 (0.477)
GDP	0.932*** (0)	7.44** (0.003)	0.856*** (0)	114*** (0.000)	1.01*** (0)
UNEMPLOYMENT			0.0640 (0.091)		
SCHOOL	0.0400 (0.899)	0.329 (0.879)	0.251*** (0.000)	-35.1 (0.307)	0.0129 (1)
POPULATION	0.003*** (0)		0.004*** (0)		0.003*** (0)
EAST	0.222*** (0)	-0.0102 (0.671)		31.3*** (0.000)	0.270*** (0)
STUDENTS-Mathematics	2.25** (0.002)	5232 (0.189)	3.38* (0.011)	303 (1)	
RESEARCH- Mathematics	1.83e-05 (0.077)	0.000346 (0.603)	6.46e-06 (1)	0 (1)	1.15e-05* (0.047)
STUDENTS-Informatics					0.288* (0.011)
RESEARCH- Informatics				4.99 (1)	
STUDENTS-Physics				6055* (0.032)	
RESEARCH -Physics	1.81e-17*** (0)	0 (0.863)	0 (0.833)		6.94e-22 (0.053)
Cox-Snell pseudo R^2	0.981	0.962	0.977	0.962	0.981

Table 8 Best and alternative models in the software industry

Variable	Best model	Alternative model 1	Alternative model 2
EMPLOYMENT			0 (1)
LOCATION QUOTIENT	0.832*** (0)	0.780*** (0)	-33.7*** (0.001)
DENSITY	0.0661* (0.014)	0.0838* (0.011)	13.5 (0.083)
GDP	0.991*** (0)	0.943*** (0)	46.0** (0.003)
UNEMPLOYMENT		0.0238 (0.385)	
SCHOOL	0.0346 (0.310)	0.107* (0.014)	3.85 (0.802)
POPULATION	0.00846*** (0)	0.00801*** (0)	
EAST	0.775*** (0.001)		-156*** (0.001)
STUDENTS-Law			3222 (0.499)
RESEARCH -Law	9.25e-06 (0.057)	1.04e-05 (0.060)	101 (0.350)
STUDENTS-Economics			
RESEARCH - Economics	9.16e-06 (0.282)	1.23e-05 (0.076)	16428 (0.221)
Cox-Snell pseudo R^2	0.617	0.602	0.453
Moran's I	0.121*** (0)	0.122*** (0)	0.0160*** (0)

Table 9 Best and alternative models in the business service industry