

Four Essays on
Human Capital Externalities

Dissertation zur Erlangung des akademischen Grades
doctor rerum politicarum (Dr. rer. pol.)

eingereicht im Fachbereich IV (Wirtschafts- und Sozialwissenschaften,
Mathematik, Informatik und Wirtschaftsinformatik)
der Universität Trier

vorgelegt von Daniel F. Heuermann

Gutachter: Prof. Dr. Dr. h.c. Dieter Sadowski
Prof. Dr. Jens Südekum

Eingereicht am: 23. April 2009

To my Grandfather

*” Whenever walking with two other people,
I will always find a teacher among them.”*

Confucius, approx. 500 BC.

Table of Contents

Acknowledgements	ix
Introduction: Human Capital Externalities	1
Paper I: Human Capital Externalities and the Urban Wage Premium – Two Literatures and Their Interrelations (with Jens Südekum and Benedikt Halfdanarson)	19
Paper II: Human Capital Externalities in Western Germany	47
Paper III: Career Networks and Job Matching – Evidence on the Microeconomic Foundations of Human Capital Externalities ...	91
Paper IV: Reinventing the Skilled Region: Human Capital Externalities and Industrial Change	131
Conclusion: Human Capital Externalities and Regional Policy	171
Full List of References	185

Acknowledgements

This dissertation is the result of the research I conducted within the three years during which I was enrolled as a PhD student at the Graduate Centre of Excellence in Rhineland-Palatinate on ‘*The Design of Efficient Labor Market Institutions in Europe*’. Without this institutional environment and the people shaping its research agenda, values, and ambience, this dissertation would not exist in its present form. I therefore first of all wish to thank the founding members of the Graduate Centre of Excellence for their perseverance in attracting and gathering financial resources, for their skillfulness in organizing the curriculum, and for the personal support and advice they provided the Graduate Centre of Excellence with.¹ Generous financial support from the Land Rhineland-Palatinate and the University of Trier, without which this project would not have been possible, is also greatly acknowledged.

I am deeply indebted to my supervisors Prof. Dr. Dr. h.c. Dieter Sadowski and Prof. Dr. Jens Südekum for their relentless personal support and advice. I wish to sincerely and cordially thank both of them for constantly encouraging me to indispensably follow my own research interests, while at the same time always reaching out a helping hand and providing me with the crucial advice I was in need of at the important junctions of the project.

I am grateful to Prof. Dr. Oliver Fabel, Prof. Dr. Eberhard Feess, Prof. Dr. Laszlo Goerke, Prof. Dr. Anthony Ogus, and Prof. Dr. Ronald Schettkat for their beneficial advice on numerous occasions. As Associate Members of the Institute of Labor Law and Industrial Relations they not only over and again improved my research through criticism and encouragement alike, but, as did my two supervisors, also taught me the excitement of giving valuable advice without asking for anything back.

I also wish to thank Dr. Henry G. Overman, who by teaching an insightful and inspiring course on ‘*The Economics of European Integration*’ at the LSE unknowingly brought my search for an adequate PhD topic to an early end by sparking my interest in the causes and dynamics that shape regional wage and income differentials within and between countries alike.

¹ The academic members of the Graduate Centre of Excellence are Prof. Dr. Peter Axer, Prof. Dr. Gregor Bachmann, Prof. Dr. Dres. h.c. Rolf Birk, Prof. Dr. Ursula Dallinger, Prof. Dr. Axel Haunschild, Prof. Dr. Georg Müller-Fürstenberger, Prof. Dr. Thomas Raab, Prof. Dr. Dr. h.c. Dieter Sadowski, and Prof. Dr. Paul Windolf. My thanks goes to each of them indiscriminately for establishing and/or continuing to support the Graduate Centre of Excellence located in the Institute for Labor Law and Industrial Relations in the European Community.

Three of the four papers constituting this dissertation investigate the issue of human capital externalities by means of empirical analyses. These analyses would not have been possible without access to the excellent data sets provided by the Institute for Labor and Employment Research, which I am very grateful for. In addition, my personal thanks goes to the whole team, and above all Dr. Peter Jacobebbinghaus, Nils Drews, and Dirk Oberschachtsiek, for their excellent technical advice, as well as for the optimism we shared during long hours solving data and Stata issues. They not only showed me how to make the best out of already fine data, but also taught me how in the end to make friends with the city of Nuremberg.

Finally, my personal thanks goes to my parents Christel and Friedo Heuermann, my deceased grandfather Gottfried Markmann, and to Johanna Speer for their love, support, and never ending patience.

Trier, April 23rd 2009

Daniel F. Heuermann

Introduction: Human Capital Externalities

Why do equally qualified workers earn higher wages in some regions within a country than in others? In general, regional differences in productivity and wages have been found to prevail in virtually all countries investigated so far. In the US, for which most evidence is available, systematic differences in regional wage levels have been robustly shown to amount up to more than thirty percent. Despite considerable political efforts of fostering equal standards of living across regions, differences in regional wage levels are of substantial size across German regions, too. These differences cannot be ascribed to systematic wage gaps between Eastern and Western Germany alone.¹ In fact, Map I shows that in 2001 average gross daily wages also differ by more than ten percent between regions within Western Germany. These differences are neither of a temporary nature, nor exclusively attributable to the spatial sorting of workers with respect to their skills. Map II, which displays the distribution of average wages in Western Germany in 1975, provides evidence that regional wage structures have by and large prevailed for the last thirty years. Since regional wage levels differ substantially even within the relatively homogenous group of highly qualified workers, sorting effects alone cannot account for differences in regional average wages. As indicated by Map III, highly qualified workers in the highest quintile of regions receive average gross daily wages of about 130 Euros, i.e. about twelve percent more than their colleagues in the lowest quintile.

What drives such persistent differences in average regional wages? Three types of arguments have been put forth in the literature. First, low rates of firm and worker mobility may lead to substantial frictions in the process of regional adjustment. With the existence of market frictions, regional wage differences do not display true regional differences in productivity, but are a mere expression of lagged adjustments to regional economic shocks. However, since regional wage differentials in Western Germany have persisted over decades even for highly qualified workers, who display the highest rate of mobility, market frictions alone are unlikely to account for the bulk of regional wage differentials. A second set of arguments relates wage differentials to regional differences in natural or infrastructural endowments. By means of illustration, agriculture is more productive in sunny regions, while manufacturing industries benefit from being close to transportation hubs like ports or airports. This type of argument can account for wage differentials in industries which

¹ In this dissertation we focus on regional wage differentials and human capital externalities across regions in Western Germany. We exclude Eastern Germany for two reasons. First, data on Eastern Germany are available only from 1992 onwards, whereas data are available for Western Germany from 1975 until today. Second, due to a large-scale devaluation of educational degrees in Eastern Germany at the time of reunification, information on the highest degree of education are incommensurable between workers in Eastern and Western Germany. Since our analysis relies on educational degrees as a core variable, we exclude Eastern Germany in order to avoid inconsistent or biased results.

rely on natural resources and transport infrastructure as inputs for production. It does, however, not explain why persistent wage differentials also prevail in the service sector, which is less dependent on natural resources and the transportation of goods. Finally, a third set of arguments regards regional differences in productivity as being endogenous to the spatial structure of economic activity. Theories on increasing returns to agglomeration, and on localized external effects from human capital have been established as the two main approaches within this school of thought.

Theories on increasing returns to agglomeration argue that regional productivity rises with economic density. Numerous theoretical models show that firms and workers are more productive in cities because they benefit from larger product markets, from matching effects in the labor market, and from improved opportunities to exchange productivity relevant knowledge. Spatial proximity to suppliers and customers in larger product markets allows firms to economize on transaction costs. In addition, consumers benefit from having access to a larger variety of products. Furthermore, larger urban labor markets allow for more efficient job matches between workers and firms. Finally, the transmission of knowledge is facilitated in cities since spatial proximity facilitates learning through communication and observation (see Duranton/Puga 2004 for an overview of the microeconomic foundations of human capital externalities). Numerous empirical studies in this literature have found each of these mechanisms to matter for higher wages prevailing in urban areas.

Theories on localized external effects from human capital regard regional wage differentials as being driven by differences in the regional aggregate levels of education. In general, workers in skilled regions are assumed to become more productive through improved opportunities for social learning. The core assumption here is that workers acquire productivity relevant knowledge through face-to-face communication and observation. Since opportunities for the exchange of information depend on the educational environment a worker is located in, the diffusion of productivity relevant knowledge increases with the level of aggregate education.

In line with this intuition, a number of microeconomic models express the intensity of knowledge exchange as a function of aggregate human capital (see Jovanovic/Rob 1989, Glaeser 1998, Jovanovic/Nyarko 1995). However, despite the prominence of human capital externalities in the theoretical literature, the potential importance of aggregate human capital for wage differentials across German regions has by and large gone unnoticed so far. Furthermore, although the existence of human capital externalities has been validated empirically for other countries, the exact mechanisms through which workers benefit from aggregate education are not well understood yet.

This dissertation is inspired by the scarcity of evidence on the size of productivity effects from aggregate human capital in Germany, as well as by the general lack of understanding of how such effects come about. Taking the prevailing ignorance on the existence of human capital externalities in Germany as our point of departure, we first investigate whether regional wage differentials in Western Germany are rooted in the existence of localized increasing returns to aggregate education. Going beyond an analysis of the mere existence of human capital externalities, we then proceed by shedding light on the microeconomic mechanisms through which productivity effects from aggregate education come about.

Before outlining the agenda of the dissertation in more detail and summarizing our main findings, we wish to introduce the intuition underlying the idea that productivity effects arise from social returns to local human capital endowments. In the next subsection we therefore clarify the reasoning behind this argument and provide an overview of the state of affairs in contemporary research.

1. Human Capital Externalities: Idea and State of Affairs in the Literature

Although dissenting on the mental and neurological processes involved, contemporary theories on human learning agree that individual knowledge and skills are predominantly developed through a person's interaction with her environment (Driscoll 1994). In fact, one of the most robust findings on processes of learning is that a person's factual knowledge, as well as her understanding of conceptual frameworks are shaped through social interaction (Donovan/Bransford/Pellegrino 1999). Yet, the importance of such interaction for acquiring knowledge and skills varies with the type of information to be transmitted. In general, the need for direct communication for the exchange of information increases with the extent to which information is not codifiable. According to von Hippel (1994), since most human skills and expertise are of a distinctly tacit nature, they are transmitted through direct communication and observation. Consequently, the acquisition and transmission of tacit, non-codifiable knowledge takes place first and foremost on a local level.

Although by its very nature hard to measure, tacit knowledge is of substantial importance for economic activity (Polanyi 1958). In fact, Cowan (2001) shows that a growing complexity of economic processes brings about rising costs for the codification of information. Hence, an increasing share of knowledge is embodied in workers and therefore, by definition, of a tacit, non-codified nature. Such tacit knowledge comprises technological information about products and processes of production, as well as knowledge about product and factor markets.

Various studies provide evidence that tacit knowledge is diffused through social interaction within local industries. For example, Saxenian (1994) argues that the computer industry in Silicon Valley gains considerable advantage from the quick diffusion of information on products, markets, and career opportunities through face-to-face communication and, even more importantly, through workers changing jobs between firms. Acknowledging the importance of local interaction for the diffusion of tacit knowledge within industries, Alfred Marshall (1890: 271) notes that “the mysteries of the trade become no mysteries but are, as it were, in the air”.

The diffusion of non-codifiable knowledge increases with local levels of aggregate education for two reasons. First, the regional stock of productivity enhancing tacit knowledge is likely to be correlated with the local level of education. Second, the size of personal networks and thereby the potential for social exchange can be robustly shown to rise with individual education (see Fischer 1982, Grossetti 2007). Consequently, the size and information content of social networks not only depend on a worker’s own level of education, but also on the education of others surrounding him. The accessibility of productivity enhancing tacit knowledge for each worker therefore increases with the local aggregate level of education. Since individuals benefit from investments into education made by others, social returns from the stock of local human capital exceed the sum of private returns. Thus, human capital externalities arise because workers incur productivity benefits by learning from the skills of others without compensating them (Arrow 1962). If, in turn, a worker’s productivity and his propensity to innovate rise with the skills and the knowledge of others around him, then aggregate regional or national human capital endowments can be expected to positively affect individual wages and overall economic growth.

In line with this reasoning, most studies on the matter agree that human capital externalities are a core source of endogenous economic growth. Systematic enquiries into the role of human capital endowments for economic growth go back to the theoretical contribution by Lucas (1988), who shows that continuous technological progress can arise from aggregate levels of human capital, which accelerate the diffusion of knowledge within an economy. Subsequent empirical studies have substantiated the existence of social returns to education on the macroeconomic level by showing that national levels of education are robustly associated with higher rates of economic growth (see e.g. Mankiw/Romer/Weil 1992). More recent advances on the matter have primarily come from studies in regional economics, which took advantage of the increased availability of micro datasets in order to investigate the role of regional levels of education for individual wages and productivity.

Microeconomic approaches in this branch of the literature have predominantly employed Mincerian wage equations to investigate whether external effects from aggregate levels of education raise regional productivity and wages. Table I provides an overview of the most important studies in this line of research. Rauch (1993) is the first to show that productivity enhancing effects of aggregate human capital are capitalized in individual wages and rents. While Rauch relies on a simple cross-section estimator, methods employed in these studies have become increasingly sophisticated over time, with different types of fixed effects and a broad set of instrumental variables now belonging to the standard repertoire. Since in Paper I we survey the literature and the results obtained therein in greater detail, we restrain ourselves here to a brief summary of the contemporary state of affairs within the research on productivity effects from aggregate human capital.

As Table I indicates, earlier studies predominantly employ the regional average years of schooling as an indicator for regional human capital endowments and provide evidence that increasing regional average education by one year raises individual wages by approximately five percent due to external effects from human capital. This line of enquiry has, however, increasingly entered troubled waters since influential contributions by Acemoglu/Angrist (2000) and Ciccone/Peri (2006) have found no or at best very small external productivity effects from average levels of education. In contrast, more recent studies have come to employ the share of highly qualified workers as a measure of aggregate human capital. Studies by Moretti (2004b), Fu (2007), and Rosenthal/Strange (2008) provide robust evidence that increasing the regional share of workers holding at least a Bachelor's degree by one percent raises regional wage levels by between .4 and 1.9 percent. The size of these effects is found to vary with the group of workers investigated.²

2. Research Agenda of the Dissertation

Agglomeration externalities and social returns to human capital can be regarded as rivaling explanations for regional wage differentials. In addition to sharing the same object of study, both literatures are closely related to each other since they employ similar econometric methods in order to identify the returns to agglomeration and aggregate education, respectively. Despite apparent similarities, both literatures have

² The importance of the regional share of highly qualified workers for regional productivity is corroborated by studies on population growth. Simon (1998), Simon/Nardinelli (2002), Glaeser/Shapiro (2003), and Südekum (2008) show that a ten percent increase in the share of college graduates holding at least a B.A. degree is robustly associated with an increase in annual population growth between .1 and .6 percent. Findings by Shapiro (2006) indicate that about two-thirds of this growth is due to enhanced productivity arising from external effects from aggregate human capital.

up to now only very occasionally taken notice from each other. This mutual ignorance is unfortunate for two reasons. First, since aggregate education increases with the level of regional agglomeration, it remains an open question to which extent higher human capital levels in cities are responsible for higher urban wages. Secondly, since both literatures face the same challenges of identification, with issues of endogeneity and unobserved heterogeneity being among the most prominent, each strand can substantially benefit from adopting methodological improvements made in the respective other.

In Paper I we relate methods and approaches employed in both literatures to each other and summarize the existing evidence on the extent to which human capital externalities are responsible for the occurrence of urban wage premia. Surveying the two literatures we conclude that human capital externalities play a small but significant role for higher wages in cities. Based on our comparison of the methods employed in each strand we then make concrete suggestions on how our understanding of the sources of regional wage differentials can be improved by a more thorough integration of econometric approaches developed in both literatures.

With respect to Germany, our knowledge about the role of agglomeration externalities for regional wage differentials, as well as about the underlying microeconomic mechanisms through which such effects arise, is far more developed than our understanding of wage determining effects of social returns to regional education. The importance of agglomeration externalities for regional wage differentials has been investigated by Haas/Möller (2003) and Lehmer/Möller (2009), who find regional wages in Germany to increase on average by about two percent with a doubling of city size. Lehmer/Ludsteck (2008) show that external effects from agglomeration arise from higher matching efficiency in urban labor market and from improved opportunities for social learning in cities. In contrast, no evidence on wage effects from aggregate education or on the microeconomic mechanisms through which human capital externalities arise exists so far.

This gap in the literature is startling since descriptive evidence suggests that human capital externalities might play a substantial role for the emergence of wage differentials across regions in Western Germany. In fact, Maps I and IV provide evidence of the close correlation between regional educational endowments and average wages of highly qualified workers. Table II, which illustrates in more detail that high wages of highly qualified workers frequently coincide with high human capital levels, further emphasizes the potential importance of human capital externalities as an explanation for regional wage differentials.

Consequently, in Paper II we estimate Mincerian wage equations in order to investigate the importance of human capital externalities as a driving force behind wage differentials across German regions. Correcting for the endogeneity of regional education by means of instrumental variables we provide evidence that aggregate regional education has a substantial impact on individual wages. We find that increasing the regional share of highly qualified workers by one percent raises wages for highly qualified workers by 1.8 percent, and by .6 percent for non-highly qualified workers. Differentiating the importance of regional human capital externalities by industry we show that human capital externalities are more pronounced in manufacturing than in the service sector, which we take as evidence that pecuniary human capital externalities prevail in manufacturing, while technological externalities are equally important in both sectors (Scitovski 1954, Acemoglu 1996).

While providing robust evidence for the existence of social returns to education, the literature on human capital externalities has been very unspecific about the microeconomic mechanisms through which such effects come about. As mentioned above, human capital externalities have frequently been found to be more pronounced when using the regional share of highly qualified workers rather than the average level of education as an indicator for aggregate human capital. Moretti (2004a) and Krueger/Lindahl (1999) argue that while the share of highly qualified workers yields external productivity effects through improved opportunities for social learning, an increase in average levels of education unfolds effects predominantly through non-market externalities, such as reductions in crime rates or improved health related behavior. While this way of reasoning explains differences in productivity effects associated with the two indicators, it can, however, not belie the fact that the literature on human capital externalities is plagued by a notorious inconclusiveness on how effects from human capital arise on a microeconomic level.

Traditionally, the literature on human capital externalities has assigned productivity enhancing external effects from education to technological knowledge spillovers alone. Thus, Marshall (1890), Arrow (1962), and Lucas (1988) assume that workers tacitly learn from each other about products and processes of production. The importance of technological spillovers is confirmed by Jaffe/Trajtenberg/Henderson (1993), who show that patents and their citations are geographically concentrated, indicating that the spread of tacit knowledge is highly localized. However, as pointed out by Duranton (2006), there might be more to human capital externalities than learning about processes of production alone. In fact, analogous to the spillover of technological knowledge, aggregate human capital may lead to a more efficient diffusion of tacit information of career opportunities within local labor markets.

In Paper III we therefore analyze whether improved opportunities for efficient job matches can be regarded as a microeconomic source of human capital externalities. Specifically, we investigate whether aggregate human capital facilitates the diffusion of information on career opportunities and thereby improves matching efficiency in the labor market. Our results are strongly affirmative of the idea that improved job matching effects in skilled regions complement productivity effects from the transmission of technological knowledge. We find workers to change jobs more often early in life and to incur larger wage increases in human capital intensive areas when changing jobs. Both results support the notion that workers are better informed about potential career paths and efficient job matches and therefore change jobs early in life so as to benefit from higher wages and productivity.

The fact that we find wage gains from aggregate human capital to arise only when workers change jobs indicates that dynamic labor markets are a prerequisite for social returns to human capital to unfold productivity enhancing effects. Thus, workers benefit from the diffusion of information on career opportunities only if dynamic labor markets allow them to change jobs easily and to thereby reap wage gains from more efficient matches. Similarly, with respect to the diffusion of technological knowledge, Almeida/Kogut (1999) provide evidence that technological knowledge is transmitted between firms first and foremost through worker who change firms. Thus, the availability of information on careers and production processes unfolds wage effects only if workers can make productive use of their knowledge through job changes. Surprisingly, the role of dynamic labor markets for the occurrence of human capital externalities has largely gone unnoticed so far in estimations on the size of productivity effects from aggregate human capital.

In Paper IV we therefore analyze the complementarity between local human capital endowments and dynamic labor markets. More specifically, we investigate whether regional industrial change, i.e. the turnover of jobs between local industries, and high levels of aggregate education are of joint importance for productivity effects from human capital externalities to emerge. In contrast to the existing literature, which has treated social returns from education largely as a static concept, our findings strongly support the notion that aggregate human capital does not raise wages in and by itself, but requires dynamic local labor markets in order to unfold productivity effects. In general, we find industries characterized by both pronounced job turnover and strong human capital endowments to benefit most from human capital externalities. In addition, productivity enhancing effects from aggregate human capital accrue predominantly to growing firms which have access to a large supply of highly qualified workers in regions characterized by high levels of job turnover.

3. Core Findings on Human Capital Externalities

In sum, the *Four Essays on Human Capital Externalities* constituting the present dissertation provide a coherent view on the size, the nature, and the dynamics of human capital externalities across German regions. Four general insights emerge.

First, our overview of the literature shows that human capital externalities exist as a real world phenomenon and to a small but significant extent can be regarded as being responsible for higher wages in urban areas. Based on our comparison of the literatures on social returns to human capital and agglomeration externalities, we encourage a more thorough integration of both literatures in order to benefit from methodological improvements made in either branch and to thereby further our understanding of the true causes behind regional wage differentials.

Second, we show that human capital externalities are a driving force behind wage differentials across German regions. We find that increasing the share of highly qualified workers by one percent raises wages of highly qualified and non-highly qualified workers by 1.8 and .6 percent respectively. The occurrence of social returns to human capital differs substantially between manufacturing and the service sector.

Third, counteracting the general impression that productivity enhancing external effects from human capital arise mainly through the diffusion of knowledge on processes of production, we show that workers in human capital rich regions benefit from improved opportunities for labor market matching. In general, aggregate human capital is associated with larger between-job wage growth and with workers changing jobs more often early in life in skilled regions.

Fourth, industrial change and regional human capital need to be jointly present in order for external productivity effects from education to arise. Hence, human capital externalities increase local wages through job turnover in skilled labor markets. On the microeconomic level, we show that growing firms benefit from human capital externalities arising from a large supply of skilled workers in dynamic labor markets.

The next four chapters contain the four papers which constitute this dissertation. The final chapter concludes by discussing the policy implications emerging from our results. Given the research focus of the Graduate Centre of Excellence within which this dissertation was written, we therein first and foremost address the question of how efficient labor market institutions in Germany and Europe should be designed so as to maximize economic gains from social returns to human capital.

References

- Abel, Jason R. and Todd M. Gabe. 2008. Human Capital and Economic Activity in Urban America. *Staff Report* No. 332. New York: Federal Reserve Bank.
- Acemoglu, Daron. 1996. A Microfoundation for Social Increasing Returns in Human Capital Accumulation. *Quarterly Journal of Economics* 111: 779-804.
- Acemoglu, Daron and Joshua Angrist. 2000. How Large Are Human Capital Externalities? Evidence from Compulsory Schooling Laws; in: Bernanke, Ben and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual*. Cambridge, MA: MIT Press.
- Almeida, Paul and Bruce Kogut. 1999. Localization of Knowledge and the Mobility of Engineers in Regional Networks. *Management Science* 45: 905-17.
- Arrow, Kenneth. 1962. The Economic Implications of Learning by Doing. *The Review of Economic Studies* 29: 155-73.
- Ciccone, Antonio and Giovanni Peri. 2006. Identifying Human-Capital Externalities: Theory with Applications. *Review of Economic Studies* 73: 381-412.
- Cowan, Robin. 2001. Expert Systems: Aspects of and Limitations to the Codifiability of Knowledge. *Research Policy* 30: 1355-72.
- Davies, Jim B. 2002. Empirical Evidence on Human Capital Externalities. Working Paper 2003-11, Department of Finance, Canada.
- Donovan, M. Suzanne, John D. Bransford and James W. Pellegrino. 1999. *How People Learn: Bridging Theory and Practice*. Washington DC: National Academy Press.
- Driscoll, Marcy P. 1994. *Psychology of Learning for Instruction*. Needham, MA: Allyn&Bacon.
- Duranton, Gilles and Diego Puga. 2004. Micro-foundations of Urban Agglomeration Economies; in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Duranton, Gilles. 2006. Human Capital Externalities in Cities: Identification and Policy Issues; in: Arnott, Richard and Daniel McMillen (eds.) *A Companion to Urban Economics*. Oxford: Blackwell Publishing Ltd.
- Fischer, Claude S. 1982. *To Dwell Among Friends: Personal Networks in Town and City*. Chicago: University of Chicago Press.
- Fu, Shihe. 2005. What Has Been Capitalized into Property Values: Human Capital, Social Capital, or Cultural Capital? *CES Working Paper* 05-25. Washington: US Census Bureau.
- Fu, Shihe. 2007. Smart Café Cities: Testing Human Capital Externalities in the Boston Metropolitan Area. *Journal of Urban Economics* 61: 86-111.
- Glaeser, Edward L. 1999. Learning in Cities. *Journal of Urban Economics* 46: 254-77.
- Glaeser, Edward L. and Jesse M. Shapiro. 2003. Urban Growth in the 1990s: Is City Living Back? *Journal of Regional Science* 43: 139-65.
- Grossetti, Michael. 2007. Are French Networks Different? *Social Networks* 29: 391-404.
- Jaffe, Adam, Manuel Trajtenberg and Rebecca Henderson. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics* 108: 577-98.
- Jovanovic, Boyan and Yaw Nyarko. 1995. The Transfer of Human Capital. *Journal of Economic Dynamics and Control* 19: 1033-64.

- Jovanovic, Boyan and Rafael Rob. 1989. The Growth and Diffusion of Knowledge. *Review of Economic Studies* 56: 569-82.
- Jurajda, Stepan. 2004. Are There Increasing Returns to Local Concentration of Skills? – Evidence on Wages and Returns to Education in Transition. *CERGE-EI Working Paper 260*. Prague: Czech National Bank.
- Kirby, Simon and Rebecca Riley. 2008. The External Returns to Education: Evidence Using Repeated Cross-Sections. *Labour Economics* 15: 619-30.
- Krueger, Alan B. and Mikael Lindahl. 1999. Education for Growth in Sweden and the World. *Swedish Economic Policy Review* 6: 289-339.
- Lehmer, Florian and Johannes Ludsteck. 2008. The Returns to Job Mobility and Inter-Regional Migration. *IAB Discussion Paper 6/2008*, Institute for Labour and Employment Research.
- Lehmer, Florian and Joachim Möller. 2009. Interrelations between the Urban Wage Premium and Firm-Size Wage Differentials: A Micro Data Cohort Analysis for Germany. Forthcoming: *Annals of Regional Science*.
- Liu, Zhiqiang. 2007. The External Returns to Education: Evidence from Chinese Cities. *Journal of Urban Economics* 61: 542-64.
- Lucas, Robert E. 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* 22: 3-42.
- Mankiw, N. Gregory, David Romer and David N. Weil. 1992. A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107: 407-37.
- Marshall Alfred. 1890. *Principles of Economics*. London: Macmillan and Co.
- Möller, Joachim and Anette Haas. 2003. The Agglomeration Differential Reconsidered: An Investigation with German Micro Data 1984-1997; in: Bröcker, Johannes, Dirk Dohse and Rüdiger Soltwedel (eds.). *Innovation Clusters and Interregional Competition*. Berlin: Springer.
- Moretti, Enrico. 2004a. Human Capital Externalities in Cities; in: Henderson, James V. and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Elsevier: San Diego, Oxford, London.
- Moretti, Enrico. 2004b. Estimation the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data. *Journal of Econometrics* 121: 175-212.
- Moretti, Enrico. 2004c. Workers' Education, Spillovers, and Productivity: Evidence from Plant-Level Production Functions. *American Economic Review* 94: 656-90.
- Polanyi, Michael. 1958. *Personal Knowledge: Towards a Post-Critical Philosophy*. Chicago. Chicago: University of Chicago Press.
- Rauch, James E. 1993. Productivity Gains from Geographic Concentration of Human Capital: Evidence from the Cities. *Journal of Urban Economics* 34: 380–400.
- Rosenthal, Stuart S. and William C. Strange. 2008. The Attenuation of Human Capital Spillovers. *Journal of Urban Economics* 64: 373-89.
- Rudd, Jeremy. 2000. Empirical Evidence on Human Capital Spillovers. *FEDS Discussion Paper 2000-46*.
- Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Scitovsky, Tibor. 1954. Two Concepts of External Economies. *Journal of Political Economy* 62: 70-82.
- Shapiro, Jesse M. 2006. Smart Cities: Explaining the Relationship between City Growth and Human Capital. *Review of Economics and Statistics* 88: 389-432.

- Simon, Curtis J. 1998. Human Capital and Metropolitan Employment Growth. *Journal of Urban Economics* 43: 223 – 43.
- Simon, Curtis J. and Clark Nardinelli. 2002. Human Capital and the Rise of American Cities 1900-1990. *Regional Science and Urban Economics* 32: 59-96.
- Strawinski, Pawel. 2008. External Returns to Education in Poland. *MPRA Paper 11598*. University Library of Munich, Germany.
- Südekum, Jens. 2008. Convergence of the Skill Composition across German Regions. *Regional Science and Urban Economics* 38: 148-59.
- von Hippel, Eric. 1994. Sticky Information and the Locus of Problem Solving: Implications for Innovation. *Management Science* 40: 429-39.

Appendix

Table I – History of Thought on Human Capital Externalities in Regional Economics

Author	Year of Publication	Title of Article	Measure of Aggregate HC	Journal of Publication
<i>Empirical Papers on Regional Human Capital and Productivity</i>				
James Rauch	1993	Productivity Gains from Geographic Concentration of Human Capital	Average	<i>Journal of Urban Economics</i>
Jeremy Rudd	2000	Empirical Evidence on Human Capital Spillovers	Average	Working Paper
Daron Acemoglu/ Joshua Angrist	2000	How Large are the Human Capital Externalities?	Average	<i>NBER Macroeconomics Annuals</i>
Enrico Moretti	2004	Estimating the Social Return to Higher Education	Share	<i>Journal of Econometrics</i>
Enrico Moretti*	2004	Workers' Education, Spillovers, and Productivity	Share	<i>American Economic Review</i>
Stepan Jurajda	2004	Are There Increasing Returns to Local Concentration of Skills?	Share	Working Paper
Shihe Fu	2005	What Has Been Capitalized into Property Values?	Share	Working Paper
Antonio Ciccone/ Giovanni Peri	2006	Identifying Human-Capital Externalities	Average	<i>Review of Economic Studies</i>
Shihe Fu	2007	Smart Café Cities	Share	<i>Journal of Urban Economics</i>
Zhiqiang Liu	2007	External Returns to Education: Evidence from Chinese Cities	Average	<i>Journal of Urban Economics</i>
Stuart Rosenthal/ William Strange	2008	The Attenuation of Human Capital Spillovers	Share	<i>Journal of Urban Economics</i>
Jason Abel/ Todd Gabe	2008	Human Capital and Economic Activity in Urban America	Share	Working Paper
Simon Kirby/ Rebecca Riley	2008	External Returns to Education: Evidence Using Repeated Cross-Sections	Average	<i>Labour Economics</i>
Pawel Strawinski	2008	External Returns to Education in Poland	Average	Working Paper
<i>Survey Papers</i>				
Jim Davies	2002	Empirical Evidence on Human Capital Externalities	-	Working Paper
Enrico Moretti	2004	Human Capital Externalities in Cities	-	<i>Handbook of Regional and Urban Economics</i>
Gilles Duranton	2006	Human Capital Externalities in Cities: Identification and Policy Issues	-	<i>Companion to Urban Economics</i>

Notes: *Average* indicates that the respective study employs Average Regional Education, as measured by the average years of schooling within a given population, as an indicator for the level of aggregate education; *Share*, in turn, refers to the number of workers holding a university degree (usually defined as a BA-Degree or higher) as a share of the total workforce.

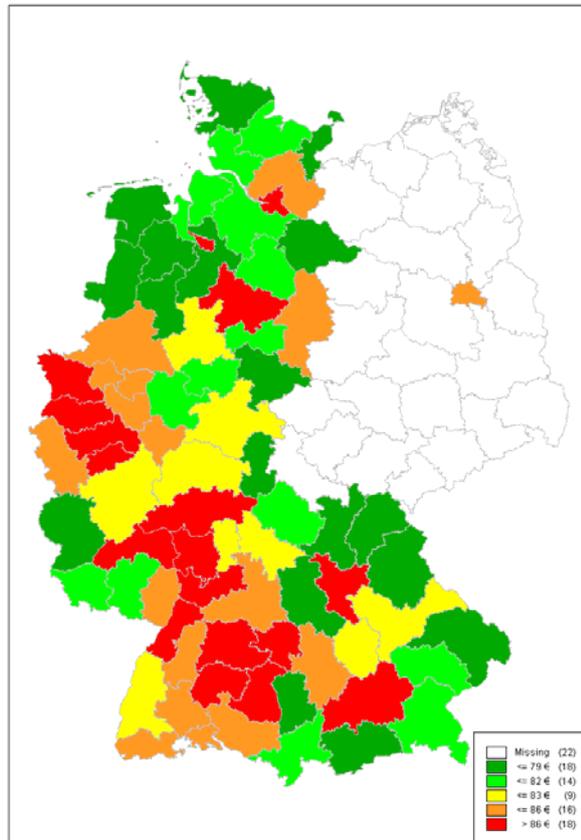
*The study by Moretti (2004) is an exception to the general rule that all studies listed here employ Mincerian wage equations as their core identification strategy since Moretti estimates firm-level production functions in order to identify human capital externalities. Notwithstanding this methodological difference we list it here so as to account for its substantial impact within the literature.

Table II – Regional Human Capital Endowments and Wage Differentials

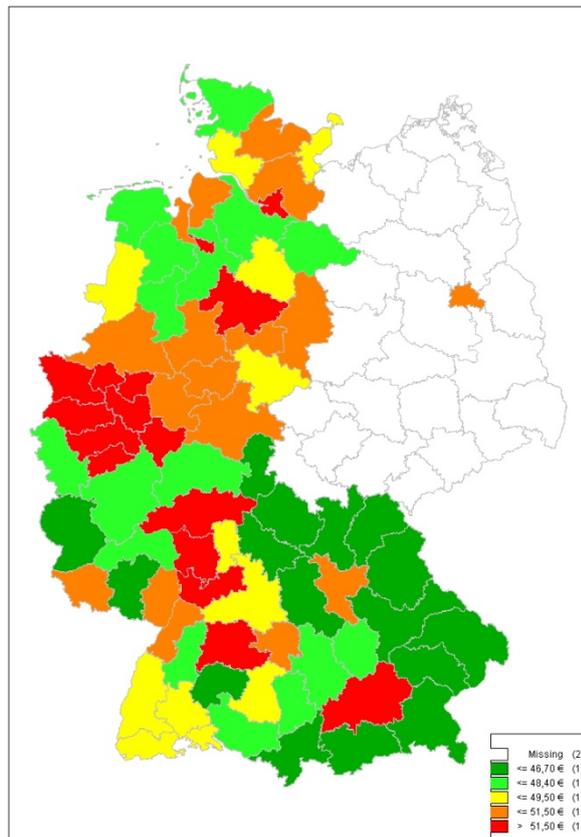
Region	Core City	Share of HQ	Region	Core City	Ø Wages for HQ
München	München	21,7	Ostwürttemberg	Schwäbisch-Gmünd	141,3
Rhein-Main	Frankfurt	18,7	Rhein-Main	Frankfurt	138,66
Bonn	Bonn	18,4	München	München	137,58
Berlin	Berlin	17,6	Rhein-Neckar	Mannheim/ Heidelberg	136,29
Hamburg	Hamburg	16,7	Stuttgart	Stuttgart	135,68
Starkenburger Land	Darmstadt	16,2	Bayerischer Untermain	Aschaffenburg	134,19
Stuttgart	Stuttgart	15,7	Mittlerer Oberrhein	Karlsruhe	133,98
Rhein-Neckar	Mannheim/ Heidelberg	15	Donau Iller	Ulm	133,88
Köln	Köln	14	Würzburg	Würzburg	133,2
Mittelfranken	Nürnberg/ Fürth	13,3	Schleswig-Holstein Südwest	Steinburg	131,82
Bremen	Bremen	13,2	Emscher-Lippe	Recklinghsn./ Bottrop	131,45
Mittlerer Oberrhein	Karlsruhe	13	Köln	Köln	130,63
Hannover	Hannover	12,5	Dortmund	Dortmund	130,44
Düsseldorf	Düsseldorf	12,4	Augsburg	Augsburg	130,41
Rheinhessen-Nahe	Mainz	12,3	Duisburg/Essen	Duisburg/ Essen	130,14
Bodensee-Oberschwaben	Ravensburg	12,2	Düsseldorf	Düsseldorf	130,02

Notes: The column *Share of HQ* contains the regional share of highly qualified workers as measured by the percentage share of workers within a regional workforce holding a degree from a university or a technical college in 2001; the column *Ø Wages for HQ* contains the raw regional average daily gross wage for highly qualified workers in 2001.

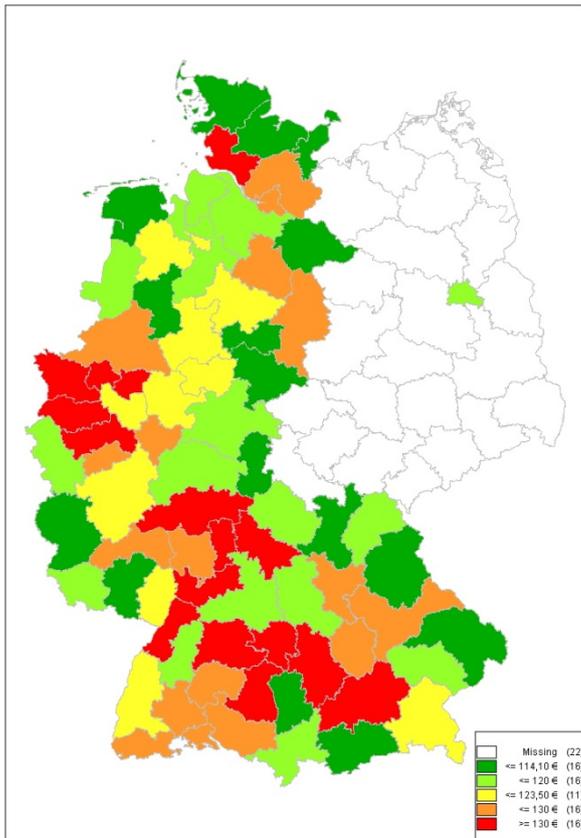
Map I: Average Regional Wages, 2001



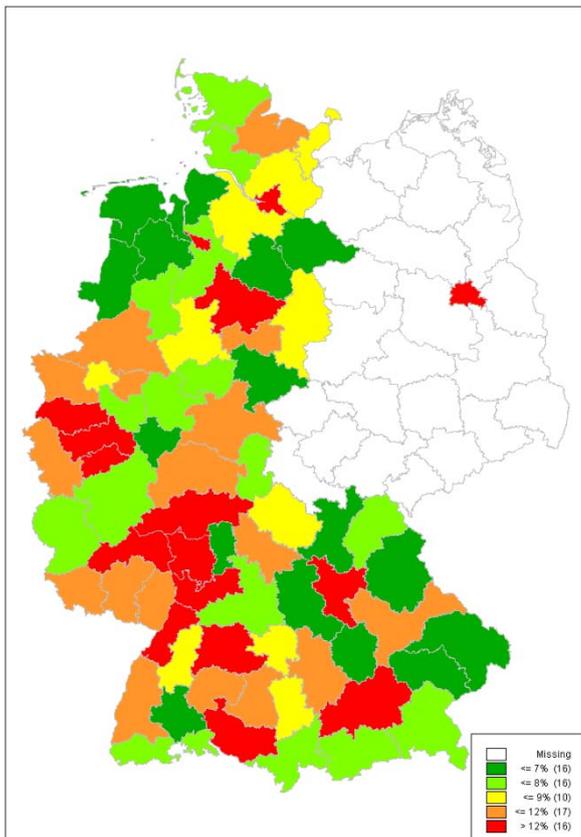
Map II: Average Regional Wages, 1975



Map III: Average Regional Wages of Highly Qualified Workers, 2001



Map IV: Regional Share of Highly Qualified Workers, 2001



Human Capital Externalities and the Urban Wage Premium – Two Literatures and Their Interrelations

(together with Benedikt Haldrup and Jens Südekum)

Abstract

In this paper we survey the recent developments in two empirical literatures at the crossroads of labor and urban economics: Studies about localized human capital externalities (HCE) and about the urban wage premium (UWP). After surveying the methods and main results of each of these two literatures, we highlight several interrelations between them. In particular we ask if HCE can be interpreted as one fundamental cause of the UWP, and we discuss if one literature can conceptually learn from the other.

Keywords: Local Labor Markets, Agglomeration, Human Capital Externalities, Urban Wage Premium
JEL Categories: D62, J24, J31, R11

I. Introduction

The rise of cities has marked human history for centuries, in fact for at least as long as written sources can testify. As of 2005, the urban share of the world population has already reached 49 percent and is heading for 60 percent in 2030. In more developed regions this share has already reached three quarters. Therefore, it is clearly necessary to understand the economics of cities in order to understand the workings of society as a whole.¹

It has been known for a long time that earnings of workers are higher in densely populated areas, and written sources indicating this fact date back more than one hundred years (Weber 1899). Attempts at measuring and explaining this **urban wage premium (UWP)** are on the other hand rather recent. The core objective of studies in the UWP literature is to identify the extent to which the density of economic activity in cities has a genuine influence on workers' productivity and to disentangle this "true" impact of urban location on labor productivity from other effects.² At the same time, the literature on localized **human capital externalities (HCE)** has emerged as a separate branch in the field of labor economics. Studies on HCE are concerned with external effects arising from education and typically aim to identify their magnitude by analysing the influence that the aggregate level of human capital has on individual wages. Most of the literature on HCE is also relatively new and still far from having reached a consensus. Surprisingly, despite being both concerned with the sources of interregional wage differentials, the two strands of literature have evolved rather separately so far.

The objective of this paper is therefore to take a closer look at the interrelations between these two lines of research and to describe how they relate to one another. In the next two sections we first provide a separate overview of the literature on the UWP and on HCE, respectively. Going beyond existing surveys, Section 4 then looks deeper into their interrelations, examines the main similarities and differences, and asks if there is scope for methodological improvement through mutual learning. Afterwards, we discuss the economic interrelations by asking to which extent HCE can be regarded as one fundamental cause behind the UWP.

¹ We use the terms "city" and "metropolitan area" interchangeably.

² Excellent surveys on theory and empirics of agglomeration have been written by Duranton/Puga (2004), Rosenthal/Strange (2004), and Moretti (2004a). Our survey adds value to these overviews in at least two respects. Firstly, we include more recent contributions. Secondly and more importantly, we adopt a novel focus by providing an in-depth discussion of the interrelations of the UWP and the HCE literature.

Reviewing the current state of art in both literatures and quantifying the effects typically identified, we reach the following main conclusions: (1) there exists a “true” UWP of modest but non-negligible size, (2) workers earn higher wages in human capital intensive areas through the workings of HCE, (3) both literatures can be improved by taking into account what the other literature has achieved so far, (4) HCE are one but not the only cause behind the true UWP.

II. The Urban Wage Premium (UWP)

Weber (1899) documents rural-urban wage differences in Prussia in the late 19th century, both in terms of numbers of workers earning enough to be taxable and in terms of the daily earnings of unskilled workers across city sizes. These comparisons all indicate higher earnings in cities. More recent studies confirm that average wages are considerably higher in cities than in rural areas, and that the “raw” UWP is increasing in city size. In a seminal contribution, Glaeser/Maré (2001) report that average wages in metropolitan areas with more than 1 million inhabitants are about 36 percent higher than outside these areas. The raw UWP for smaller cities ranges at about 21 percent.³

II.1. Sorting, Unobserved Heterogeneity and Ability Bias

The fundamental objective in the UWP literature is to disentangle whether higher urban wages are the result of a “true” effect of urban location on the productivity of labor, or whether they arise from the fact that workers with more favourable (observable and/or unobservable) characteristics choose to live in cities. There is an abundance of studies showing that regions differ largely in the composition of their workforces, with urban workers being on average more educated than rural ones (see e.g. Simon/Nardinelli 2002). As people are typically free to migrate within countries, the location of individuals is not random and systematic differences between rural and urban workforces are the result of endogenous location decisions. The main conceptual difficulty with this sorting mechanism is that workers differ not only with respect to observable characteristics, but also along several other dimensions that are not easily observable to the econometrician.

³ Consistent stylized facts for other countries are provided by Möller/Haas (2003) and Lehmer/Möller (2009) for Germany, Di Addario/Patacchini (2008) for Italy and Combes/Duranton/Gobillon (2008) for France. The latter report that average wages in Paris are 15 percent higher than in other large French cities and 60 percent higher than in French rural areas.

Controlling for basic observable characteristics such as experience or ability as measured by the Armed Forces Qualification Test (AFQT), Yankow (2006) reports a UWP that still ranges between 17 percent and 22 percent for big cities. This is lower than the 36 percent raw UWP, but still larger than standard estimates for other wage premia, e.g. for union members. These numbers do not necessarily imply, though, that labor is really 17 to 22 percent more productive in cities. The following example illustrates the problem: Unobservable motivation or ambition are likely to influence earnings as well, but this ability is only imperfectly captured by AFQT scores. Motivated workers may be attracted to cities if ambition is higher rewarded or if motivated people prefer typical urban amenities. This would lead to endogenous sorting of ambitious workers who are predisposed to higher earnings into urban areas. If these sorting effects are not taken into account, observed wage differences between cities and rural areas may be incorrectly interpreted as true productivity effects of urban location.

Instrumenting for urban location has turned out to be difficult due to the lack of suitable instruments that predict urban location but are unrelated to individual wages. **Glaeser/Maré** (2001) therefore tackle the issue of ability bias by including worker fixed effects in a panel model using individual wage data. Including fixed effects eliminates unobserved heterogeneity, but the identification of the UWP now relies on individuals who have changed urban status over time, i.e. on migrants between cities and rural areas. Using a fixed effects estimator reduces the UWP to around 11 percent for large cities. Yankow (2006) adopts a similar approach and also finds that the UWP is reduced by about 50 percent when including individual fixed effects.⁴

The study by **Combes/Duranton/Gobillon** (2008) uses a two stage estimation procedure on a large panel of French workers. They first regress individual wages on standard worker characteristics and worker fixed effects, as well as on area-year fixed effects, industry fixed effects, and local characteristics of the industry of employment. They find that worker fixed effects are highly correlated with area fixed effects, suggesting that sorting plays an important role for the explanation of spatial wage disparities. In a second step, they examine the area fixed effects in greater detail by regressing them on variables capturing local endowments and local interactions between industries, with the latter being interpreted as proxies for different

⁴ Including fixed effects assumes the existence of a worker-specific “intercept” term for individual wages. This may, however, not be fully adequate, as urban workers may have different experience-wage profiles. Yankow therefore employs an estimator which allows for individual-specific experience profiles.

agglomeration forces.⁵ Combes/Duranton/Gobillon find that area fixed effects are mostly explained by employment density, but the magnitude of the effect is substantially lower than suggested by previous estimates that do not take individual sorting into account (such as Ciccone/Hall 1996). The main message of their study is that most of the variation in spatial wages can be explained by worker fixed effects and, hence, by the sorting of heterogeneous agents across locations.⁶

Gould (2007) argues that the inclusion of worker fixed effects is not enough to uncover the causal effects of urban location on individual productivity. This is due to two reasons which are both rooted in the implicit assumption of the fixed effects model that individual unobservable characteristics are orthogonal to *changes* in the workers' location. Firstly, this is problematic because wage increases after a move to the city do not have to arise because the same worker in the same job is more productive in an urban environment. They might simply stem from the fact that the worker has changed into a job which offers better career perspectives, which in turn may cause an instantaneous jump in wages or faster wage growth over time. Analogously, the observation that wage premia remain after workers move back to the countryside may reflect improved career perspectives of workers migrating back, rather than true productivity effects. Secondly, wage increases after a change to the city may arise from the fact that workers can absorb tacit knowledge faster through unobservable learning capacities. In this case, productivity effects from unobservable characteristics are neither time nor location independent. Gould (2007) develops a structural two-stage model which accounts for the self-selection process of workers moving to cities. His approach takes into account the correlation between the residual of the wage regression and the individual location choice, but this comes at the cost of not including any workers fixed effects, which requires assumptions about the distribution of residuals. His findings indicate that for blue collar workers practically no true UWP exists, implying that higher urban wages arise because more able workers self-select into urban jobs. For white collar workers a genuine UWP of about 11 percent remains. This wage premium is transferable back to rural areas, which suggests that cities actually make white collar workers more productive and that jobs in the city can be regarded as a human capital investment (see Peri 2002 for a related theoretical argument).

⁵ Controlling for industrial composition is motivated by the literature which investigates if agglomeration effects arise from either industrial diversity or specialization (see Combes/Overman 2004 for a survey).

⁶ A related earlier study is **Duranton/Monastiriotis** (2002), who show that individual returns to educational degrees have become more similar across space and time. Since, however, returns for different levels of education have diverged and since human capital has become increasingly agglomerated, interregional inequality has increased on an aggregate level even though individual returns to educational attainments have become more similar.

II.2. Costs of Living and the UWP in Real Terms

A related hypothesis is that high urban wages may simply compensate for high urban housing prices and costs of living (COL). A principal difficulty when addressing this hypothesis is the limited availability of data. Researchers have to rely on proxies, most notably the price indices developed by the American Chamber of Commerce Research Association (ACCRA). Using this data, **Glaeser/Maré** (2001) report that in fact no significant UWP in real terms exists for big cities. This observation is important as it helps to understand why workers do not constantly migrate to cities. However, assuming that relocation costs are not prohibitive it is puzzling why firms selling their products nationwide or even on international markets are willing to pay high (nominal) urban wages. Thus, the UWP should be an expression of higher worker productivity in urban areas, since otherwise firms would relocate over time.

The fundamental point in the debate on whether to use nominal or real wages is that while spatial differences in nominal wages can be interpreted as productivity differences, regional differences in real wages reflect differences in workers' utility rooted in urban amenities. Therefore, a full adjustment of nominal wages with the ACCRA index leads to an underestimation of productivity effects of agglomeration because people may be willing to accept lower wages so as to be able to enjoy urban amenities. Addressing this issue, DuMond/Hirsch/MacPherson (1999) suggest a partial COL-adjustment based on ACCRA data, which **Yankow** (2006) in turn uses in his study on the UWP. Consistent with Glaeser/Maré (2001) he finds that the UWP vanishes in real terms with a full COL-adjustment. However, when using a partial COL-adjustment the UWP reduces to 5 to 12 percent (depending on how unobserved ability is controlled for) but remains significant.

II.3. Economic Mechanisms behind Higher Urban Labor Productivity

Several studies aim to shed light on the economic mechanisms responsible for higher urban wages. This discussion is closely related to the general empirical literature on agglomeration, which faces the basic problem that different theories often lead to observationally equivalent outcomes. While most theories predict higher productivity and wages in agglomeration areas, they typically differ in their detailed implications of how (quickly) these gains come about.

As is well known, Marshall (1890) identifies knowledge spillovers, sharing of specialized inputs, and constant market for skills as sources of increasing returns from agglomeration. Conceptualizing Marshall's ideas according to their microeconomic

foundations, Duranton/Puga (2004) root agglomeration externalities in learning, sharing, and matching mechanisms. Learning mechanisms are facilitated in cities due to the face-to-face nature of communication. Diversified cities can foster the generation of new ideas and technologies as posited by Jacobs (1969) and Duranton/Puga (2001). The economies of sharing usually refer to indivisible goods and facilities, a larger number of specialized inputs, or risk sharing in the presence of labor market fluctuations. Finally, agglomeration may improve the quality of matches between workers and jobs (see Helsley/Strange 1990, Kim 1990).

Empirical studies on the UWP have tried to discriminate between these theories by investigating if urban location gives rise to a level or a growth effect on wages, if wage gains are realized mainly with job changes or on-the-job, and if human capital acquired in the city is transferable to rural areas. In these analyses, wage level effects are usually supposed to indicate the presence of matching or sharing externalities which accrue to workers directly after they have moved to the city. If wage gains arise immediately after changing jobs within the city, this allows to draw the conclusion that the UWP arises mainly from matching externalities. If, in contrast, wages grow over time after a move to the city, this is frequently assigned to learning effects. If workers keep a higher level of wages even after moving back to rural areas, this is usually taken as further evidence for learning effects in cities. It has to be noted, however, that the reverse is not necessarily true since workers incurring wage reductions when moving back to rural areas may have acquired knowledge which is simply not transferrable to rural areas, as it might be the case with city-specific or industry-specific knowledge.

The first analysis on wage level vs. growth effects is provided by **Glaeser/Maré** (2001). They include dummy variables for rural-to-urban and urban-to-rural migrants, respectively, and investigate wages at different time periods before and after the move. While a metropolitan wage premium of around 17 percent exists for non-moving city-dwellers, movers to metropolitan areas seem to quickly realize substantial wage gains of about 8 percent already in the first year, and around 12 percent within five years, as compared to rural stayers. The level effect implies a sudden productivity increase upon moving, which is, however, not sufficient for newcomers to instantaneously catch up with long-term city workers. Subsequent wage growth indicates gradual wage effects from being in the city. An additional finding is that movers out of the city do not appear to suffer a complete loss of the UWP. The evidence thus suggests that the UWP consists of an immediate level effect, and a growth effect that is realized only over a period of several years. The former effect seems to amount to roughly two thirds of the UWP.

The study by **Yankow** (2006) also starts with a wage level analysis. Controlling for worker fixed effects he concludes that an UWP of around six percent exists for large cities (and none for medium-sized cities). In his wage growth analysis, Yankow finds that only part of this UWP is incurred immediately by rural-to-urban migrants, while the rest is realized only over time. Yankow also distinguishes between within-job and between-job changes in wages. If improved matching opportunities in cities matter, between-job wage gains should be higher in urban areas while learning effects should lead to higher within-job wage growth. While Yankow's results reveal no significant difference in between-job wage growth between urban and rural workers, they show that workers in urban areas change jobs more often. It is mainly through this mechanism that faster wage growth can be observed in cities.

Wheeler (2006) particularly focuses on wage growth. In contrast to Yankow, he finds job changes in urban areas to be associated with larger wage gains than in rural areas. He concludes from this finding that between-job wage growth is more important than within-job growth, lending support to matching theories rather than to the learning hypothesis. In general, his results indicate that wage growth is positively linked to three different measures of local market scale: population, density, and industrial diversity. The notion that agglomeration unfolds productivity benefits through the provision of a broader set of matching opportunities is confirmed by **Finney/Kohlhase** (2008), who show that early in their career young men change jobs more frequently in urban areas. A more complex interpretation of patterns of job changes is provided by **Bleakley/Lin** (2007), who find regional economic density to have a negative impact on the frequency of intra-regional job changes for all but young workers. They interpret this finding as evidence that cities provide superior opportunities for young workers to change jobs up to the perfect match in which they stay thereafter. Workers in rural areas, in contrast, have to change jobs more often for a perfect match to occur. In a dynamic perspective, these differences in matching opportunities are important as a source of the UWP for two reasons. On the one hand, workers' firm or industry specific human capital depreciates faster in the countryside due to a higher rate of job changes. Secondly, young workers in cities have a higher incentive to invest more into firm or sector specific human capital, since they can expect to stay longer within one firm or industry (see Wheeler 2001).

Several papers carry the idea of improved matching opportunities in cities further and investigate if urban workers change jobs more often within industries, and are thereby able to accumulate industry-specific human capital. The first analysis on this issue is provided by **Wheeler** (2008), who shows that early in their career workers in cities change industries more frequently than their colleagues in rural regions. This

probability decreases with the number of job changes, indicating that workers build up industry specific human capital once they have discovered for which industry they are best suited. Similarly, **Freedman** (2008) argues that industrial clustering enables workers to hop between jobs within one industry more frequently, and thereby to find a job which offers them optimal career and learning perspectives. Consistent with this interpretation, Freedman finds within-job wage growth to be more pronounced within urban industrial clusters than outside. Finally, the study by **Gould** (2007) is also informative with respect to the mechanism that drives the UWP. It shows that human capital acquired in the city is fairly well transferable back to rural areas. This finding suggests that cities provide learning opportunities through which white collar workers become sustainably more productive.

II.4. The UWP for Different Types of Workers

While most studies focus on the UWP that arises for the average urban worker, some studies explicitly take different types of workers into account. **Gould** (2007) argues that while white-collar workers receive a sizeable true UWP, higher urban wages for blue-collar workers arise exclusively from sorting effects. Consistently, **Möller/Haas** (2003) find an agglomeration wage premium in Germany for high-skilled but not for low-skilled workers. More generally, some types of skills (in contrast to degrees of education) receive an extra reward in cities but others do not. Pioneering work comes from **Bacolod/Blum/Strange** (2009), who identify skills along three broad categories: cognitive, people, and motor skills. They construct an index of job skill intensity using the Dictionary of Occupational Titles through which they derive workers' skills from the work they are doing. The authors find evidence that workers with cognitive and people skills, as opposed to those endowed with motor skills, receive an UWP. Their findings also indicate that requirements for cognitive and people skills are higher for white collar professions, while motor skills are frequently associated with blue collar workers.

II.5. The Geographical Scope of the UWP

If proximity is beneficial and raises wages, the question that logically arises is “what proximity?”. This question regards the spatial reach of agglomeration economies. Since **Openshaw/Taylor** (1979) the problem of defining appropriate geographic units which cover economic processes in a meaningful way is known to the profession as the ‘Modifiable Areal Unit Problem’ (MAUP). Inconsistencies between geographical definitions may arise from differences in scale and zonation of units. Certain agglomeration mechanisms might be relevant on one level of aggregation but not on

others. Zoning describes the problem that different types of entities are prone to have different shapes and therefore might segment economic actors into different units which in turn is likely to alter empirical results.

In practice, most studies use an administrative or official definition of a city or metropolitan area. Glaeser/Maré (2001), Yankow (2006), and Gould (2007) define a big city as an SMSA with more than 1 million inhabitants. Other studies (e.g. Wheeler 2006, Ciccone/Hall 1996) directly control for density or market size. Combes/Duranton/Gobillon (2008) use French employment areas (zones d'emploi) which are defined so as to minimize commuting flows across areas. In general, despite the different definitions of geographical entities, the literature on the UWP has come up with largely consistent results. In fact, Briant/Combes/Lafourcade (2007) show in a related study that while the choice of region size matters slightly for the traceability of agglomeration externalities, differences in the shape of regions do not.

II.6. Spatial Sorting of Industries and Firms as Sources of the UWP

There is a longstanding debate on whether benefits from agglomeration are rooted in either localization or in urbanization economies (see Combes/Overman 2004 for a survey). The study by **Wheaton/Lewis** (2002) is of particular interest here, because it investigates the effects from specialization and concentration on workers' wages. The authors estimate Mincerian wage functions augmented by industrial and occupational variables and find strong evidence for wage gains from specialization and concentration. The more specialized SMSAs are with respect to industries and occupations, the larger are the wage premia in these industries and occupations. Similarly, wage premia are higher in SMSAs where a respective industry or occupation is concentrated.

An argument similar to the spatial sorting of industries relates to the spatial sorting of firm types. **Lehmer/Möller** (2009) show that firms in urban areas are relatively larger than in the countryside and that larger firms pay higher wages than small firms. Controlling for firm size, they find that the raw UWP of about 15 percent reduces to about 8 percent, and that large firms pay a premium of about 11 percent independent of location. Given the sorting of large firms into cities this intra-firm wage premium may be misinterpreted as an UWP if not properly controlled for. On the other hand, spatial differences in firm sizes might be rooted in agglomeration economies which induce firms to be larger in urban areas. If firm size varies systematically with urban density, benefits from agglomeration might be underestimated when controlling for firm size.

The idea of spatial sorting is carried further by **Mion/Naticchioni** (2009), who control for simultaneous worker and firm sorting by employing linked employer-employee data (LEED). Their results indicate that 75 percent of the raw wage variation in Italy can be attributed to the spatial sorting of workers while the spatial sorting of firms affects wages only to a minor degree. These results emphasize the advantages of using LEED data in order to address the role of assortative matching. This approach is therefore likely to be pursued much further in this literature.

III. Human Capital Externalities (HCE)

While we are not aware of any other up-to-date survey of the UWP literature, various authors have already reviewed the HCE literature (Moretti 2004a, Duranton 2006). This allows us to be rather brief.

III.1. Types of HCE

In general, three different types of HCE can be differentiated between. Market externalities, which can be further subdivided into technological and pecuniary externalities, are frequently juxtaposed with non-market externalities. Our primary focus in this survey is on the importance of HCE as a wage determining factor, hence on market externalities. Technological HCE arise if educated workers increase the productivity of other workers, for example through processes of informal learning, without being compensated. Jovanovic/Rob (1989) show theoretically that proximity to qualified individuals can increase the acquisition of skills and facilitate the diffusion of knowledge. In contrast, pecuniary HCE arise from market interactions. Assuming costly labor market search and complementarity between human and physical capital, Acemoglu (1996) develops a framework in which investment decisions in physical capital are based on expectations on the level of education. Since firms anticipate future educational attainments from the contemporary aggregate level of human capital, a more educated workforce leads to an increase in physical capital investment. In this case, HCE arise because workers with low human capital will also enjoy a productivity increase through working with an increased stock of physical capital.

III.2. Main Strategies for Identifying HCE

Moretti (2004a) describes three possible strategies for estimating regional HCE, based on inter-regional differences of either (1) the productivity of firms, (2) costs of land,

or (3) workers' wages. The logic of each of these identification frameworks rests on the fundamental spatial equilibrium concept by Roback (1982). If HCE exist, so the argument goes, firms and workers are more productive in areas with high levels of human capital. This in turn should attract firms and workers. Given a fixed supply of land, this process increases land prices and rents. In equilibrium, both firms and workers must be indifferent between locations. Hence, higher productivity must be offset by higher wages and higher rent.

The biggest problem with the identification approach that uses firm productivity is the limited availability of data, since neither data on firms' costs of production, nor on their input and output is easily available (see, however, Moretti 2004c). The problem with land prices is that the assumption of fixed regional quantities (land or housing stock) need not hold.

The third and most frequently applied method is a comparison of wages of workers in cities with differing levels of human capital. The principal challenge of this approach is very similar to the UWP literature: wages are affected by a multitude of factors, which makes it difficult to identify the true causal effect of HCE. An important consideration in the light of the spatial equilibrium concept is whether HCE affect only the productivity of labor, or whether they also have an effect on the quality of life. If regional human capital endowments entail a consumption value for individuals, workers are willing to accept lower wages to live in educated areas. In other words, rents and land prices should be higher in human capital intensive areas provided HCE are positive, but the net effect on nominal wages depends on whether human capital is predominantly a productive or consumptive amenity. As a consequence, even an insignificant coefficient of local human capital on individual wages does not necessarily indicate the absence of HCE, since productive and consumptive effects may simply cancel out.

III.3. The Mincerian Approach

Most authors have estimated the size of HCE using augmented Mincerian wage functions (Mincer 1974). The earliest attempt to quantify HCE using this approach is **Rauch** (1993), who takes an amenity model based on Roback (1982) as a starting point in order to investigate the impact of aggregate level of human capital, measured by average education and average experience, on individual wages. In addition he estimates a hedonic model of land rent, proxied by housing expenditure. Exploring the possibility of omitted variables bias, Rauch controls for area of residence within the US, and for the presence of other local amenities, i.e. cultural activity, weather,

and population. His estimates indicate that an increase of average education by one year increases wages significantly by 3.3 percent. In contrast, wages do not seem to be affected by average experience. The effect on rents is estimated at 11.2 percent for a one year increase in average education and 1.3 percent for the same increase in average experience. As his results also indicate private returns of 4.8 percent to an additional year of education, HCE account for as much as almost half the overall returns to education. In sum, Rauch's results support the notion that human capital externalities exist and are of a meaningful size.

Using state level data from 1978 until 1991, **Rudd** (2000) repeats Rauch's analysis. While for single years Rudd finds positive effects of state-wide educational attainment consistent with Rauch's results for metropolitan areas, he finds no evidence for the existence of externalities after including state fixed effects. This leads him to the conclusion that a state's average education level is merely a good proxy for other unobservable factors affecting productivity.

In line with Rauch, **Dalmazzo/de Blasio** (2007) argue that it is necessary to consider both wages and rents since consumption externalities may counteract wage growth.⁷ Rauch found the effect of an additional year of local average education on rent to be 11.2 percent. Taking his estimate of the land share of output to be 6.4 percent, this corresponds to a 0.7 percent increase in total factor productivity that may not be identified in wage equations. Dalmazzo/de Blasio estimate the effect of human capital externalities on land rents and find it to range between six and twenty-four percent.

III.4. Instrumental Variable Approaches and the Endogeneity of Education

One of the most serious problems in the identification of HCE is the potential endogeneity of education. As pointed out by Acemoglu/Angrist (2000), higher incomes might cause more schooling. Just as in the UPW literature, another serious concern is that workers with more favourable (un-)observable characteristics self-select into human capital intensive regions. A final aspect of the endogeneity problem are shocks which simultaneously affect a city's earnings and education level. Moretti (2004b) cites the upswing in San Jose in California following the internet boom as an example for these types of shocks, which drive up demand for qualified staff, push up wages, and attract educated workers simultaneously. The combination of these changes is prone to mistakenly be interpreted as the existence of HCE.

⁷ Glaeser/Kolko/Saiz (2001) provide evidence of faster rent growth in cities with more educated populations since 1970, a finding which they assign to the existence of consumption externalities.

Acemoglu/Angrist (2000) address reverse causality between wage and education by using past compulsory state schooling laws (CSL) and child-labor laws (CLL) as instrumental variables for average schooling.⁸ Using this instrumental variable approach reduces social returns to human capital to statistically insignificant one percent in the 1960-1980 censuses. One concern that comes to mind considering their study is that their target group consists of white middle-aged males only. One might suspect that this group is on average better educated and may therefore be more of a cause of externalities rather than a beneficiary. Secondly, CSLs might force children to acquire a certain minimum education, but they do not affect choices regarding higher education, which might be the true cause of HCE.

Moretti (2004b) controls for unobserved heterogeneity through individual and city fixed effects. In addition, in order to address unobserved heterogeneity and potential endogeneity of schooling he employs the presence of a land-grant college and the regional age structure as instruments. Another innovation in Moretti's work is his measure of education. He uses the share of college educated workers, rather than the average education level. This is important, because the two measures of local human capital are likely to have different effects. An increase in the local level of college education may lead to productivity growth, while an increase in years of schooling is more likely to unfold non-market effect such as reductions in crime rates.⁹ Pooling all education groups Moretti finds a significant and positive effect of about 1.1 to 1.3 percent from a one percentage point increase in the share of college graduates. Increasing the share workers with high-school degree yields no notable effect. Furthermore, less educated groups generally benefit more from growth in higher education groups.¹⁰

An innovative approach to the endogeneity problem is provided by **Muravyev** (2008) in his study on Russia. The system of wage determination in the USSR had little if anything to do with actual productivity and effectively barred any sorting based on productivity or wages, which was additionally impeded by migration controls.

⁸ Using schooling laws as instruments for aggregate schooling has inspired a series of studies following this approach. A remarkable example is Liu (2007), who uses regional enforcement of Chinese schooling laws as an instrument for regional average schooling and finds localized human capital externalities in China to range between 11 and 13 percent.

⁹ This distinction is also relevant in the context of those studies that use CSL as an instrument, since these laws specifically target groups in the lower levels but might have less to do with higher education even if they affect average education. Duranton (2006) offers this as a possible explanation as to why Acemoglu/Angrist (2000) find little evidence of HCE.

¹⁰ Closely related to Moretti (2004a) is **Heuermann** (2008), who uses the regional number of public schools and of students attending them as instruments for the share of highly qualified workers among regions in Western Germany. He identifies social returns to human capital to be in the magnitude of 1.8 percent for highly qualified workers and of .6 percent for non-highly qualified workers. In an industry-by-industry analysis he finds that HCE are more pronounced in manufacturing than in the service sector. Furthermore, this analysis also reveals that highly qualified workers seem to benefit from intra-industry knowledge spillovers, while non-highly qualified workers profit mainly from pecuniary externalities arising between industries.

Muravyev finds that the education level in 1989 is highly correlated with the one in his years of observation, 1994 and 2002, and can thus serve as a valid instrument. In his regressions Muravyev finds a significant increase in individual earnings of around 1.5 percent with an increase in the regional college share by one percentage point.

III.5. Imperfect Substitution Effects and the Constant-Composition Approach

Increasing the number of high skilled workers changes the relative factor endowments of high-skilled and low-skilled workers within an area. If workers are imperfect substitutes, a change in their relative supply affects relative factor prices. **Moretti** (2004a) finds a positive effect of the local human capital share on earnings of low-skilled and high-skilled individuals. The former finding is consistent with HCE and with imperfect substitution. The latter finding suggests, however, that HCE are present and are even sufficiently strong to overcompensate possible supply effects.

Ciccone/Peri (2006) suggest a ‘constant-composition approach’ to disentangle HCE from imperfect substitution effects. The proposition is that externalities can be identified as the change in regional average wages when holding regional skill composition constant over time. This method has the advantage that less information is needed, as it does not require instruments for aggregate human capital. Ciccone/Peri demonstrate that while the Mincerian approach identifies a positive and significant effect of aggregate human capital on wages, the constant composition method shows no significant effect. This result holds both on the city and state level and across a variety of instruments. Ciccone and Peri’s work thus casts some doubt on previously reported results. It must be noted though that since Ciccone/Peri study the same group of workers as Acemoglu/Angrist (2000), the same caveats apply to their study as they did to the latter.

III.6. Summary on HCE

Summing up, evidence from this research is conflicting both in terms of methods and results. Potential explanations are numerous since the studies differ in various aspects. First of all, the use of panel models can make a difference. The discrepancy between Rauch’s (1993) and Moretti’s (2004b) results can probably partly be assigned to Rauch’s use of a single-year sample. The size of spatial units is certainly another important factor affecting the results. Since Jaffe/Trajtenberg/Henderson (1993) provide evidence that the geographical spread of knowledge spillovers is limited, differences in the definition of local labor market can be supposed to explain parts of the divergence of the results by Moretti (2004b) and Rudd (2000). Finally,

differences in the choice of the measure of human capital and the instruments or the sample of workers might as well affect the results.

IV. Interrelations between the HCE and the UWP Literatures

The last two sections have traced the developments in the UWP and the HCE literature over the last 10 to 15 years. Table 1 in the Appendix summarizes the crucial steps.

IV.1. Problems and Solutions Shared by Both Literatures

Based on the insight that both literatures have followed a symmetric development we now proceed to systemize and discuss the core problems and methods. Both literatures have started out using augmented versions of the Mincerian wage equation. The standard model for identifying HCE reads

$$\ln W = \alpha + \beta X + \gamma Z + \phi + \varepsilon \quad (4.1)$$

where the dependent variable is the log of earnings, X is a vector of individual observable characteristics, and Z includes observable characteristics of the given area, including a measure of aggregate human capital. ϕ contains unobserved individual characteristics such as motivation or ambition. These might affect wages, but cannot be readily observed. ε is an error term with the standard properties. The size of HCE is displayed by the coefficient of aggregate human capital, i.e. in the vector γ . The standard equation for estimating the UWP reads

$$\ln W = \alpha + \beta X + \delta U + \phi + \varepsilon \quad (4.2)$$

where all previous variables are unchanged, except that U either includes dummies for urban residence or a measure of agglomeration density. δ displays the size of the UWP. The fact that equations (4.1) and (4.2) are almost identical underlines the similarity of the initial approaches and indicates the likeness of their problems. If ϕ is random and therefore not correlated with any of the other regressors, it is legitimate to ignore it and to employ a feasible general least squares estimator. If unobserved individual effects ϕ are correlated with X , U , or Z , however, this approach is

inappropriate since pushing ϕ into the error term would introduce partial correlation between ε and the explanatory variables and thereby lead to inconsistent estimates.

In both the HCE and the UWP literature, aggregate education and density are suspected to be correlated with unobserved regional wage determining characteristics like infrastructure, amenities, or regional policies. In this case an appropriate option is to find suitable instruments. A second option is to proxy for unobserved characteristics by some observable measure. This has often turned out to be a highly imperfect option, however. Both strands of the literature have therefore increasingly relied on **fixed effects and instrumental variables**. While regional fixed effects effectively control for factors remaining constant within an area, they are not able to capture regional wage determining variables that change over time and space, like regional union or government policies. The use of instrumental variables, which has turned out to be a more effective strategy here, has in turn frequently raised the question of instrument validity. Some of the instruments used seem far-fetched, like the age-structure for college share, or have been shown to be weak, like compulsory schooling for aggregate education. In still other cases, no suitable instruments can be found, such as instruments for city residence.

Another challenge is the integration of **market imperfections** into empirical investigations. A standard assumption in both strands is that firms and workers are perfectly mobile. This assumption is problematic, however, as shown in various studies particularly for European countries. However, with segmented or slowly adjusting labor markets regional differences in labor demand and supply become important wage determining factor. To date, it remains largely an open issue of how to account for these types of rigidities. In a similar vein, there may be other imperfections in labor markets that cause wages to deviate from marginal product of labor. The typical study on UWP or HCE disregards such institutional differences among regions. One exception is Yankow (2006) who shows that a higher unionization rate in urban areas explains part of interregional wage differences.

Three further problems come to mind, which have been dealt with in only one of the two strands. Effects from **imperfect substitution** described in section 3.4 have been a concern in the HCE literature, while they have not featured in research on the UWP. Still, it seems legitimate to ask how changing labor-force compositions would alter the results on the UWP. This is particularly relevant in the light of recent results that the UWP differs across skill groups (Möller/Haas 2003, Gould 2007). If workers of different groups are imperfect substitutes, changes in the relative size of the groups may affect wages. Various analyses show that skill levels are on average lower in rural

areas. Thus, if a random sample of rural workers migrates, this will lower the average skill level in the city. Given imperfect substitution this in turn must change earnings in cities for both groups for two reasons. On the one hand, an increase in economic density raises wages for both groups due to agglomeration effects. On the other hand, the imperfect substitution effect tends to increase wages for skilled workers and reduce wages for low-skilled workers. If not properly controlled for, such imperfect substitution effects lead to biased estimates of the UWP.

Secondly, the distinction between **level and growth effects** has been mainly an issue within the UWP literature. There it has been demonstrated that a significant part of the premium is a growth effect. The literature on HCE has however been reluctant to fully explore the dynamics of processes of social learning. However, if the number of job changes or the length of residence is not controlled for, HCE may be underestimated because workers may have not yet fully exploited the wage benefits from being located in a human capital intensive area.

Finally, attempts to address the **sorting of workers along unobservable characteristics** have been more widely discussed in the UWP literature. While parts of the sorting problem can be addressed by employing either individual fixed effects or some kind of observable ability measures, at least two important dimensions of sorting require more sophisticated methods: the gradual sorting of ‘better’ workers into ‘better’ firms, and the sorting of workers into jobs offering them better career perspectives.

The former issue has been tackled by Mion/Naticchioni (2009) by means of LEED, a solution which should be tried in the HCE literature as well. Similarly, it seems feasible to transfer Gould’s (2007) simulation approach to the HCE literature in order to account for self-selection of workers into cities with different human capital intensity. This probably requires defining a ‘skilled region’ and using dummy variables for residence in such skilled regions (rather than urban residence) in an adapted version of Gould’s original approach.

IV.2. HCE as a Cause for the UWP?

The evidence on HCE reviewed in section 3 suggests that wages increase with the local aggregate level of human capital, which indicates that workers are more productive in human capital intensive environments. At the same time it is well documented that cities are endowed with higher levels of human capital than rural areas. Therefore it is plausible to expect that HCE have a role to play as a driving force behind the UWP. However, although intuitive, this reasoning does not prove a

causal relationship. The core questions to be answered are twofold. On the one hand, we would like to know how much of the UWP can be uniquely attributed to HCE. On the other hand, we wish to learn about the microeconomic mechanisms through which HCE exert an impact on urban wages.

Since the notion of technological HCE mainly revolves around learning effects, there is little reason to expect benefits of HCE to accrue to workers immediately upon moving. Consequently, growth effects of urban residence may indicate the presence of HCE. Wheeler (2006), Yankow (2006), and Lehmer/Möller (2009) draw inference on learning effects from evidence on wage level and wage growth effects. Increased wage growth for city dwellers can, however, not unambiguously be taken as evidence for HCE since it may stem either from within-job wage growth, or from wage growth associated with more frequent job changes. Of these two, only within-job growth can be regarded as arising from learning effects, while between-job growth is usually interpreted as arising from improving job matches. The results by Yankow (2006) and Wheeler (2006) indicate that population density facilitates searching and matching rather than improving opportunities of social learning and knowledge exchange. While these findings do not necessarily rule out HCE as an explanation for higher urban wages, they restrict the scope for a substantial role of HCE.

In general, the limited evidence on technological externalities in the UWP literature is in line with their arguably small size identified in the HCE literature. The big picture arising from scattered evidence thus suggests that while HCE play some role, they are certainly not the whole answer to the question of which forces are responsible for the existence of an UWP.

A further opportunity for identifying the role of HCE for the UWP, which has not been fully exploited yet, is rooted in the debate on potential wage effects from regional specialization and urbanization. Empirical studies usually find that a higher degree of specialization and concentration leads to wage gains, which is usually interpreted as evidence for spillovers being limited in industrial scope (Wheaton/Lewis 2002). These studies do not have much to say, however, about the interplay between industrial concentration, HCE, and the UWP. **Wheeler** (2007) is the only study that explicitly focuses on the relation between industrial concentration and human capital externalities. Estimating hedonic wage equations containing both aggregate human capital and level of industry concentration, he finds that including both types of explanatory variables in the same regression leaves their respective highly significant effect on wages largely unchanged. Wheeler concludes that localization economies and HCE are fairly distinct phenomena.

This finding reveals that neither pecuniary nor technological HCE arise through the concentration of industry alone. In our view a logical extension of his analysis would be a detailed investigation of workers who change jobs between industries but within cities. Such an analysis of wage growth dynamics can be expected to shed light on the extent to which industries provide fertile grounds for social learning, and on the extent to which workers benefit from intra-industry knowledge spillovers.

A truly spatial view is provided by **Rosenthal/Strange** (2008), who analyze the attenuation of HCE in space. They use geographic information software to create concentric rings with diameters of 5, 25, 50, and 100 miles around the workplace of each worker. They then identify aggregate employment of all workers, and of skilled workers only, within each of these rings. In order to address the potential endogeneity of population numbers, Rosenthal/Strange use geological features like the fraction of land within each ring covered by water and the fraction of the ring underlain by bedrock. The intuition behind these instruments is that since each of them reduces the available land, it also puts a natural constrain to agglomeration without affecting wages by itself. Rosenthal/Strange find that wages increase with economic density (a result consistent with the UWP) and in particular with the density of educated workers (consistent with HCE), with the latter effects displaying a particularly strong spatial decay. Wages increase strongly if educated workers are located very close by (within 5 miles) and decrease by a factor of 2.5-3 beyond a distance of five miles. The effect of human capital concentration within 25 miles is considerably weaker.¹¹ As for general worker density, Rosenthal/Strange calculate that transforming fifty-thousand less-than-college educated workers into college educated workers within the five mile zone can be expected to yield a ten percent increase in wages. These results must be taken with a grain of salt, though, since their OLS estimates indicate only a two percent increase for the same change. This substantial difference might be due to weakness of their instruments, indicated by small first-stage F-statistics (smaller than ten with only one exception). Notwithstanding these difficulties, Rosenthal/Strange have laid the cornerstone for an innovative and promising strategy of identifying the relative importance of HCE for occurrence of the UWP.

The only study known to us that sheds light on a particular microeconomic mechanism through which HCE unfold an impact on wages is provided by

¹¹ The argument that spillovers attenuate extremely rapidly has recently been pushed further by Arzaghi/Henderson (2008), who analyze the location decision of advertising agencies in downtown Manhattan. They argue that agencies are willing to locate in extremely expensive neighbourhoods, as they trade off higher rents with the benefits of being close to other agencies. These type of knowledge spillovers, thus, appear to be extremely strongly localized and capitalize in higher rents rather than in higher wages. A consistent result comes from Fu (2007), who also finds effects from human capital to decrease very quickly beyond three miles, a finding which inspires the author to refer to human capital rich cities as 'smart café cities'.

Charlot/Duranton (2004), who investigate the importance of communication as a knowledge transmission device using data on workplace communication among a sample of French workers. Employing standard wage regressions they show that individual communication behaviour significantly affects individual wages. In a second set of regressions they show that individual communication increases with city size and, in line with findings by **Bacolod/Blum/Strange** (2009), with the overall level of education. However, both aggregate variables display much stronger direct effects on wages, rather than exerting an impact on wages through individual communication behavior. These findings yield two main insights. First, HCE and general economic density coexist as relevant wage determinants and, secondly, the direct effect through which agglomeration and aggregate education influence wages is between eight and ten times larger than their indirect effect through communication.

Finally, the discussion in section 3 on whether HCE arise mainly as either production or consumption externalities is important for our take on the importance of HCE as a cause for the UWP. If consumption externalities matter, workers would accept lower wages in human capital rich areas. Not controlling for the consumption value of local human capital will thus lead to an underestimation of the true productivity effect of HCE (**Dalmazzo/de Blasio** 2007). The extent to which regional human capital levels carry a consumption value has remained a quite unexplored issue. Since production and consumption externalities affect wages in opposite directions, we must be cautious concluding that HCE are only a minor cause behind the UWP, as long as it remains unknown to which extent human capital intensity has a consumption value for city residents.

V. Summary and Conclusions

In this paper we have surveyed two empirical literatures at the cross-roads of urban and labor economics: studies on the urban wage premium (UWP), and on localized human capital externalities (HCE). Contemplating the current state of art in both strands, we believe that it is fair to draw the following key conclusions:

-Workers earn higher wages in cities.

Early papers in the UWP literature have identified a “true” urban wage premium of between five and ten percent for workers in agglomerated areas. Controlling for the variety of confounding factors, and taking various difficulties into account, more recent papers arrive at a true urban wage premium of about three percent. This premium partly arises immediately upon moving and partly with time spent in the

city. The true UWP tends to be larger for high skilled workers. Sorting is important and must sharply be distinguished from the “true” UWP. Sorting is particularly important for low-skilled workers.

- Workers earn higher wages in human capital intensive areas.

While the evidence in this strand of literature is somewhat more controversial, several studies indicate small but significant increases in wages resulting from the presence of human capital. These wage gains are frequently in the order of about one to three percent for an additional year of average regional education, or an additional percentage-point in the regional college share.

- Both literature strands can be improved by learning from the methods applied in the respective other strand.

The two literatures have evolved in a similar way, progressing from fairly simple hedonic price equations to increasingly sophisticated approaches. In the very recent years, there have been some digressions and experiments with new methods. Given substantial problems still to be addressed in both strands, with imperfect markets, institutional rigidities, assortative matching, and a broad band of endogeneity issues being prime examples, both literatures can certainly benefit from a greater mutual awareness of the attempts and strategies employed by the respective other for solving these problems. We have tried to make some specific suggestions on how the two strands can be unified.

- HCE are one but not the only cause behind the true UWP.

Numerous attempts have been made in the literature to identify the source of the UWP. These studies provide insightful evidence on the role played by HCE as a driving force behind the UWP. It seems fair to conclude that some parts of the UWP can reasonably be traced back to the existence of HCE. At the same time there is evidence that the UWP is to a large extent rooted in other agglomeration effects essentially unrelated to HCE. Thus, HCE can only account for a fraction of the UWP.

The progress that has been made within the last fifteen years in both strands of the literature gives reason for hope that much progress can and will be made in the future.

References

- Acemoglu, Daron. 1996. A Microfoundation for Social Increasing Returns in Human Capital Accumulation. *Quarterly Journal of Economics* 111: 779-804.
- Acemoglu, Daron and Joshua Angrist. 2000. How Large Are Human Capital Externalities? Evidence from Compulsory Schooling Laws, in: Bernanke, Ben and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual*. Cambridge (Mass.): MIT Press.
- Angrist, Joshua and Alan B. Krueger. 1991. Does Compulsory School Attendance Affect Schooling and Earnings? *Quarterly Journal of Economics* 106: 979-1014.
- Arzaghi, Mohammad and J. Vernon Henderson. 2008. Networking Off Madison Avenue. *Review of Economic Studies* 75: 1011-38.
- Bacolod, Marigee, Bernardo Blum and William C. Strange. 2009. Skills in the City. *Journal of Urban Economics* 65: 136-53.
- Bleakley, Hoyt and Jeffrey Lin. 2007. Thick-Market Effects and Churning in the Labor Market: Evidence from U.S. Cities. *Reserve Bank of Philadelphia Working Paper* 07-23.
- Briant, Anthony, Pierre-Philippe Combes and Miren Lafourcade. 2008. Do the Size and Shape of Spatial Units Jeopardize Economic Geography Estimations? *CEPR Discussion Paper* No. 6928.
- Charlot, Sylvie and Gilles Duranton. 2004. Communication Externalities in Cities. *Journal of Urban Economics* 56: 581-613.
- Ciccone, Antonio and Robert Hall. 1996. Productivity and the Density of Economic Activity. *American Economic Review* 86: 54-70.
- Ciccone, Antonio and Giovanni Peri. 2006. Identifying Human-Capital Externalities: Theory with Applications. *Review of Economic Studies* 73: 381-412.
- Combes, Pierre-Philippe, Gilles Duranton and Laurent Gobillon. 2008. Spatial Wage Disparities: Sorting Matters! *Journal of Urban Economics* 63: 723-42.
- Combes, Pierre-Philippe and Henry G. Overman. 2004. The Spatial Distribution of Economic Activities in the European Union, in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Dalmazzo, Alberto and Guido de Blasio. 2007. Production and Consumption Externalities of Human Capital: An Empirical Study for Italy. *Journal of Population Economics* 20: 359-82.
- Di Addario, Sabrina L. and Eleonora Patacchini. 2008. Wages and the City. Evidence from Italy. *Labour Economics* 15: 1040-61.
- DuMond, J. Michael, Barry Hirsch and David A. MacPherson 1999. Wage Differentials Across Labor Markets and Workers: Does Cost of Living Matter? *Economic Inquiry* 37: 577-98.
- Duranton, Gilles. 2006. Human Capital Externalities in Cities: Identification and Policy Issues; in: Arnott, Richard J. and Daniel P. McMillen (eds.) *A Companion to Urban Economics*. Oxford: Blackwell.
- Duranton, Gilles and Vassilis Monastiriotis. 2002. Mind the Gaps: The Evolution of Regional Earnings Inequalities in the UK, 1982-1997. *Journal of Regional Science* 42: 219-56.
- Duranton, Gilles and Diego Puga. 2001. Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products. *American Economic Review* 91: 1454-77.

- Duranton, Gilles and Diego Puga. 2004. Micro-foundations of Urban Agglomeration Economies; in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Finney, M. and Kohlhase, J. (2008) The Effect of Urbanization on Labor Turnover, *Journal of Regional Science* 48: 311-328.
- Freedman, Matthew L. 2008. Job Hopping, Earnings Dynamics, and Industrial Agglomeration in the Software Industry. *Journal of Urban Economics* 64: 590-600.
- Fu, Shihe. 2007. Smart Café Cities: Testing Human Capital Externalities in the Boston Metropolitan Area. *Journal of Urban Economics* 61: 86-111.
- Glaeser, Edward L., Jed Kolko and Albert Saiz. 2001. Consumer City. *Journal of Economic Geography* 1: 27-50.
- Glaeser, Edward L. and David C. Maré. 2001. Cities and Skills. *Journal of Labor Economics* 19: 316-42.
- Gould, Eric D. 2007. Cities, Workers, and Wages: A Structural Analysis of the Urban Wage Premium. *Review of Economic Studies* 74: 477-506.
- Helsley, Robert W. and William C. Strange. 1990. Matching and Agglomeration Economies in a System of Cities. *Regional Science and Urban Economics* 20: 189-212.
- Heuermann, Daniel F. 2008. Human Capital Externalities in Western Germany. *IAAEG Discussion Paper* No. 05/2008, University of Trier.
- Jacobs, Jane. 1969. *The Economy of Cities*. New York: Random House.
- Jaffe, Adam B., Manuel Trajtenberg and Rebecca Henderson. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics* 108: 577-98.
- Jovanovic, Boyan and Rafael Rob. 1989. The Growth and Diffusion of Knowledge. *Review of Economic Studies* 56: 569-82.
- Kim, Sunwoong. 1990. Labor Heterogeneity, Wage Bargaining, and Agglomeration Economies. *Journal of Urban Economics* 28: 160-77.
- Lehmer, Florian and Joachim Möller. 2009. Interrelations between the Urban Wage Premium and Firm-Size Wage Differentials: A Micro Data Cohort Analysis for Germany. Forthcoming: *Annals of Regional Science*.
- Liu, Zhiqiang. 2007. The External Returns to Education: Evidence from Chinese Cities. *Journal of Urban Economics* 61: 542-64.
- Marshall, Alfred. 1890. *Principles of Economics*. London: Macmillan and Co.
- Mincer, Jacob. 1974. *Schooling, Experience, and Earnings*. New York: NBER.
- Mion, Giordano and Paolo Naticchioni. 2009. The Spatial Sorting and Matching of Skills and Firms. *Canadian Journal of Economics* 42: 28-55.
- Möller, Joachim and Anette Haas. 2003. The Agglomeration Differential Reconsidered: An Investigation with German Micro Data 1984-1997; in: Bröcker, Johannes, Dirk Dohse and Rüdiger Soltwedel (eds.). *Innovation Clusters and Interregional Competition*. Berlin: Springer.
- Moretti, Enrico. 2004a. Human Capital Externalities in Cities; in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol.4. Amsterdam: Elsevier-North Holland.
- Moretti, Enrico. 2004b. Estimation the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data. *Journal of Econometrics* 121: 175-212.

- Moretti, Enrico. 2004c. Workers' Education, Spillovers, and Productivity: Evidence from Plant-Level Production Functions. *American Economic Review* 94: 656-90.
- Muravyev, Alexander. 2008. Human Capital Externalities: Evidence from the Transition Economy of Russia. *Economics of Transition* 16: 415-43.
- Openshaw, Stan and Peter J. Taylor. 1979. A Million or so Correlation Coefficients: Three Experiments on the Modifiable Areal Unit Problem; in: Wrigley, Neil (ed.) *Statistical Applications in the Spatial Sciences*. London: Pion.
- Peri, Giovanni. 2002. Young Workers, Learning and Agglomerations. *Journal of Urban Economics* 52: 582-607.
- Rauch, James E. 1993. Productivity Gains from Geographic Concentration of Human Capital: Evidence from the Cities. *Journal of Urban Economics* 34: 380-400.
- Roback, Jennifer. 1982. Wages, Rents, and the Quality of Life. *Journal of Political Economy* 90: 1257-78.
- Rosenthal, Stuart S. and William C. Strange. 2004. Evidence on the Nature and Sources of Agglomeration Economies: in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Rosenthal, Stuart S. and William C. Strange. 2008. The Attenuation of Human Capital Spillovers. *Journal of Urban Economics* 64: 373-89.
- Rudd, Jeremy. 2000. Empirical Evidence on Human Capital Spillovers, *FEDS Discussion Paper* 2000-46.
- Simon, Curtis J. and Clark Nardinelli. 2002. Human Capital and the Rise of American Cities. *Regional Science and Urban Economics* 32: 59-96.
- Weber, Adna F. 1899. *The Growth of Cities in the Nineteenth Century*. 3rd reprint, Ithaca, N.Y.: Cornell.
- Wheaton, William C. and Mark J. Lewis. 2002. Urban Wages and Labor Market Agglomeration. *Journal of Urban Economics* 51: 542-62.
- Wheeler, Christopher H. 2001. Search, Sorting, and Urban Agglomeration. *Journal of Labor Economics* 19: 879-99.
- Wheeler, Christopher H. 2006. Cities and the Growth of Wages among Young Workers: Evidence from the NLSY. *Journal of Urban Economics* 60: 162-84.
- Wheeler, Christopher H. 2007. Do Localization Economies Derive from Human Capital Externalities? *Annals of Regional Science* 41: 31-50.
- Wheeler, Christopher H. 2008. Local Market Scale and the Pattern of Job Changes among Young Men. *Regional Science and Urban Economics* 38: 101-18.
- Yankow, Jeffrey J. 2006. Why Do Cities Pay More? An Empirical Examination of Some Competing Theories of the Urban Wage Premium. *Journal of Urban Economics* 60(2): 139-61.

Table 1: History of Thought in the HCE and UWP Literature

UWP						HCE					
Study	Approach	Instruments	Areal Unit	Sample	Findings	Study	Approach	Instruments	Areal Units	Sample	Findings
Ciccone/Hall (1996)	Labor Productivity Regressions	Railroads 1850, Past Population, Distance to Atlantic Ocean	US States, US Counties	States and Counties, 1988, Var. Sources	6%	Rauch (1993)	Mincerian Wage Regressions on Wages and Rents	Land Area (for SMSA Population)	SMSAs	All Workers, (Census 1980)	3.3% for Wages, 11.2% for Rents
Glaeser/Maré (2001)	Wage Regression with Fixed Effects on Mult. Datasets	Urbanization of Parents' Place of Birth	PUMAs, SMSAs	Various	11%	Rudd (2000)	Fixed Effects Decomposition	None	US States	All Workers, (CPS 1978-91)	No Effect
Möller/ Haas (2003)	Quantile Wage Regression with Focus on Skill Levels	None	NUTS III Regions, Germany	Male Workers (IABS 1980-97)	2.5%, Increase with Skill Level	Acemoglu/ Angrist (2000)	Instrumental Variables	Compulsory Schooling Laws, Child Labor Laws	US States	White Males Aged 40-49, (Census 1960-80)	1%
Yankow (2006)	COLI-Adjusted Wage Regressions	None	SMSAs over 250.000 Inhabitants	Young Workers (NLSY79)	5-12%	Moretti (2004b)	Instrumental Variables	Age Structure, Land Grant Colleges	SMSAs	Young Workers (NLSY79)	1.1 -1.3%
Gould (2007)	Two-Stage Self-Selection Model	None	SMSAs	Young Workers (NLSY79)	11% for White Collar Workers	Moretti (2004c)	Plant-Level Production Functions	Fraction of Large Plant Openings Among All Plants	SMSAs	Manufact. Establishm., (Census of Manufact. 1982-92)	.5 - .7%
Combes/ Duranton/ Gobillon (2008)	Decomposition of Fixed Effects	Past Popul., Past Market Potential, Mean Distance to other Empl. Areas	Zones d'Emploi (Employment Areas), France	Full-Time Workers (DADS, 1976-96)	3%	Dalmazzo/ de Blasio (2007)	Mincerian Wage Regressions on Rents	Age Structure	Local Labor Markets, Italy	All Workers, (SHIW 1993-2000)	6-24% for Rents
Lehmer/ Möller (2009)	Wage Regressions with Firm Size Controls	None	NUTS III Regions, Germany	Full-Time Workers (IABS, 1990-97)	8%	Ciccone/ Peri (2006)	Constant-Composition Approach	Age Structure, Share of African-Americans	SMSAs, US States	All Workers; White Males Aged 40-49, (Census 1970-90)	No Effect
Mion/ Naticchioni (2009)	Linked Employer-Employee Data	Past Population, Past Market Potential	Provinces, Italy	Young, Male Workers (INPS 1985-98)	1%	Muravyev (2008)	Instrumental Variables	Past Education Levels	Oblasts, Russia	All Workers, (RLMS 1994)	1.5%

Human Capital Externalities in Western Germany

Abstract

The paper sheds light on the impact of local human capital endowments on individual wages in Western Germany. Using panel data it shows that regional wage differentials are partly attributable to localized human capital externalities arising from the regional share of highly qualified workers. Employing the regional number of public schools and of students as instrumental variables, the paper shows that human capital externalities are underestimated in ordinary panel regressions for highly qualified workers due to supply shifts of workers of different skills. An analysis by sector reveals that human capital externalities are more pronounced in manufacturing than in the service sector. We find indication that highly qualified workers benefit from intra-industry knowledge spillovers, while non-highly qualified workers profit from pecuniary externalities between industries. Our findings are stable among a variety of indicators of regional human capital and robust to the inclusion of other sources of increasing returns, as well as wage curve, price level, and amenity effects.

Keywords: Human Capital Externalities, Agglomeration,
Urban Wage Premium
JEL Categories: D62, D83, J24, J31, O15

I. Introduction – Human Capital Externalities and Regional Wages

“It is an odd fact that the economic basis for major elements of public policy and expenditure depends importantly on the size of one of the least well measured of all economic phenomena: human capital externalities.”

Jim B. Davies (2002: 1)

Despite the distribution of wages and human capital being uneven between countries and within countries alike, regional human capital endowments have rather late attracted attention as determinants of regional development. The link between human capital agglomeration and regional prosperity was first pointed out by early development economists like Myrdal (1954), Kuznets (1962), Hirschman (1958), and Kaldor (1970), who emphasized that the spatial agglomeration of human capital creates benefits over and above the private returns reaped by individuals. In contemporary economic theory these social benefits are usually regarded as resulting from either market or non-market human capital externalities (Moretti 2004a). Arguments based on technological market externalities have gained prominence through Arrow (1962), Romer (1986), and Lucas (1988), who argue that human capital externalities arising from uncompensated learning processes between individuals are an important source of economic growth. Acemoglu (1996) shows that pecuniary market externalities from human capital arise if firms choose their investment in physical capital in anticipation of the average human capital of their future workers. Non-market externalities from human capital frequently mentioned in the literature include reductions in crime rates, better informed voting decisions, or improved health-related behavior (Davies 2002).

These theoretical insights as well as Rauch’s (1993) empirical finding that the geographic concentration of human capital significantly raises productivity and wages have sparked a controversial debate on the extent to which higher urban wages and productivity are the result of positive externalities from the agglomeration of human capital. Although empirical studies show that a doubling of employment density increases wages and productivity by about six percent in the US (Ciccone/Hall 1996), five percent in European countries (Ciccone 2002), and four percent in the UK (Anastassova 2006) it has remained contested to which extent this premium can be attributed to human capital externalities. Glaeser/Maré (2001) argue that while a large part of the urban wage premium is due to spatial sorting of workers with respect to observable and unobservable characteristics, human capital externalities increase urban wages by about twelve percent. In a similar vein Combes/Duranton/Gobillon (2008) assign a wage increase of about three percent to human capital externalities arising in French cities. In general, uncertainty on the

precise magnitude of human capital externalities is rooted in substantial methodological problems of identification. Ciccone/Peri (2006) emphasize that omitted regional variables constitute a serious threat to the correct identification of human capital externalities and that neglecting shifts of supply and demand of skills can lead to heavily biased estimates. Acemoglu/Angrist (2000) employ an instrumental variable strategy and show that social returns from education range below one percent and thus are substantially below earlier estimates. Notwithstanding these challenges sound theoretical reasons as well as tentative empirical evidence suggest that human capital externalities are an important determinant of productivity and wages and therefore constitute an important piece in the puzzle of uneven regional development.

Given the ardent debate on social returns to education in the US labor market it comes as a surprise that only one study (Sudekum 2008) addresses the issue of human capital externalities in the German labor market. This general retention is startling since German regions are shaped by substantial differences in economic performance with areas of agglomeration being particularly advantaged with respect to human capital, wages, and productivity. Regional wage differentials in Germany are investigated by Lehmer/Möller (2009), who identify a raw urban wage premium of about fifteen percent, and by Möller/Haas (2003), who find a doubling of employment density to raise individual wages by about 2.5 percent with these benefits increasing with individual level of skills. Sudekum (2008) is the only study that directly addresses the issue of human capital externalities by analyzing the impact of regional human capital on employment growth. His finding that regional human capital endowments positively influence employment growth of low-skilled workers does, however, support theories of neoclassical complementarities between skilled and unskilled workers rather than explanations based on human capital externalities.

Summing up, it turns out that the fundamental question of the extent to which human capital externalities are a driving force behind the urban wage premium in Germany has hitherto been left unaddressed. The present paper fills this gap and investigates whether regional wage differentials in Germany can at least partly be attributed to human capital externalities. We employ an instrumental variable approach as a central identification strategy in order to distinguish human capital externalities from other sources of regional wage disparities. Our main concern is that regional shifts in the supply of skills and other unobservable variables might bias our estimates. We therefore employ the regional number of public schools and of students attending them as instruments for the regional share of human capital. The instruments are based on the idea that future urban labor supply is a valid instrument for today's regional share of highly qualified workers. The intuition behind

our instruments is that the regional number of public schools and the number of students attending them are both closely related to regional human capital endowments since students from peripheral areas more than proportionally attend public schools in urban areas, change to the respective city's university after graduating from school, and from there enter the city's labor market. Both instruments are exogenous in Mincerian wage regressions since individual wages can reasonably be assumed not to be influenced by the number of schools or the number of students. A broad band of statistical tests corroborate our theoretical considerations on instrumental relevance and exogeneity.

Based on these instruments our analysis shows that in line with Moretti's (2004b) findings for the US human capital externalities have a substantial positive impact on individual wages in Germany and that this effect first and foremost works through the impact of the regional share of highly qualified workers. This effect is not only stable among a broad range of indicators for regional human capital, but also robust to the inclusion of other sources of increasing returns, as well as to wage curve, price level and amenity effects, and, finally, to neoclassical explanations of supply and demand. Comparing our results from instrumental variable regressions to those from regressions without instruments we find that in ordinary least squares regressions the impact of human capital externalities is heavily underestimated for wages of highly qualified and non-highly qualified workers alike, a finding we attribute to shifts in the supply of highly qualified workers which reduce wages for both types of workers through partly shared labor markets. In addition to being the first study on wage determining effects of human capital externalities in Germany, our study adds to the literature by investigating the relative importance of technological and pecuniary human capital externalities. Estimating wage regressions separately for each of the sixteen industries in our sample we find strong evidence that while highly qualified workers mainly benefit from intra-industry knowledge spillovers, wages of non-highly qualified workers are affected predominantly through pecuniary human capital externalities arising between industries. Our instrumental variable approach furthermore shows that human capital externalities are on average about fifty percent smaller in the service sector than in manufacturing which we interpret as evidence for the relative importance of pecuniary externalities in manufacturing.

The finding of substantial positive human capital externalities impacting on wages of highly skilled workers is not only of academic interest. It is also of prime importance for an adequate design of regional policy since it pinpoints a core conflict of objectives. Any regional policy committed to the objective of efficiency is certainly well advised to foster the spatial agglomeration of human capital. This is frequently done today through considerable public investments into an infrastructure for the

exchange of knowledge and information with knowledge clusters, science parks, and innovation centers being prime examples. This type of efficiency-oriented regional policy, however, stands in sharp contrast to Article 91 of the Constitution, which obliges the German government to promote an equal development of all regions Germany and to actively support the catching-up process of regions lagging behind.

Section II sets the stage for the empirical investigation by deriving an econometric model for the identification of the impact of human capital externalities on wages; Section III summarizes the data and provides descriptive evidence on the spatial distribution of wages and human capital among German regions before presenting the results from the empirical analysis in depth; Section IV concludes.

II. Human Capital Externalities: Theory and Identification

In this section we develop a simple model from which we derive testable hypotheses on how the share of skilled workers impacts on the wages of skilled and unskilled workers alike. We then contrast the idea of knowledge spillovers to other potential sources of regional wage differentials put forth in the literature, i.e. to labor pooling and input-output linkages as alternative sources of increasing returns, and to wage curve, price level, and amenity effects. From this we derive an empirical identification strategy which is capable of differentiating between these rivaling explanations.

II.1. Human Capital Externalities: Theoretical Framework

The empirical investigation in this paper relies on a simple model, which is a modified and adapted version of Moretti (2004a). It is important to note that this model is compatible with technological externalities arising from learning processes, as well as with pecuniary externalities arising from firms' expectations on future human capital. This all-encompassing model is in line with our objective to shed light on the overall size of human capital externalities in Western Germany. Like Acemoglu/Angrist, who with respect to the American labor market do "not to attempt to distinguish between these mechanisms, since they have similar implications" (1999: 6), we do not aim to quantify the relative influence of both types of externalities, an aspiration we regard as not very promising, and restrain ourselves to pointing out evidence for technological or pecuniary externalities wherever our results indicate the prevalence of either one. The model is based on a production function that uses two types of labor as input and exhibits increasing returns to human capital. More specifically,

output in region j is assumed to be produced under Cobb-Douglas technology using skilled labor (N_{1j}) and unskilled labor (N_{2j}) as inputs:

$$Y_j = (\theta_{1j}N_{1j})^{\alpha_1}(\theta_{2j}N_{2j})^{1-\alpha_1} \quad (1)$$

It is further assumed that productivity of skilled and unskilled labor θ_{ij} is a function of individual productivity enhancing skills ϕ_{ij} with $\phi_{1j} > \phi_{2j}$ and of increasing returns arising from the ratio of skilled labor to total workforce in city j .

$$\log(\theta_{ij}) = \phi_{ij} + \gamma \left(\frac{N_{1j}}{N_{1j}+N_{2j}} \right) \quad (2)$$

Obviously, with $\gamma = 0$ individual productivity depends exclusively on individual human capital with skilled workers by definition being endowed with a higher amount of human capital. If wages equal the marginal product of labor it is straightforward to see that with $s_j = (N_{1j}/N_{1j}+N_{2j})$ the logarithms of wages for skilled workers w_{1j} and for unskilled workers w_{2j} are:

$$\log(w_{1j}) = \log(\alpha_1) + \alpha_1 \log(\theta_{1j}) + (\alpha_1 - 1) \log(s_j) + (1 - \alpha_1) \log(\theta_{2j}) + (1 - \alpha_1) \log(1 - s_j) \quad (3)$$

$$\log(w_{2j}) = \log(1 - \alpha_1) + \alpha_1 \log(\theta_{1j}) + \alpha_1 \log(s_j) + (1 - \alpha_1) \log(\theta_{2j}) - \alpha_1 \log(1 - s_j) \quad (4)$$

To understand what happens to wages when the regional share of skilled workers increases we take first derivatives $d\log(w_{1j})/ds$ and $d\log(w_{2j})/ds$, which yields:

$$\frac{d\log(w_{1j})}{ds_j} = \gamma + \frac{\alpha_1 - 1}{s_j(1-s_j)} = \gamma + \frac{\alpha_1 - 1}{s_j - s_j^2} \quad (5)$$

$$\frac{d\log(w_{2j})}{ds_j} = \gamma + \frac{\alpha_1}{s_j(1-s_j)} = \gamma + \frac{\alpha_1}{s_j - s_j^2} \quad (6)$$

An increase in the share of skilled workers impacts on wages of skilled and unskilled workers in two ways, i.e. through human capital externalities γ , and through neoclassical supply effects arising from imperfect substitution of skilled and unskilled workers. Human capital externalities γ have a positive effect of the same magnitude on wages of all workers. Supply effects, in contrast, work in opposite directions for both types of workers; an increase in the share of skilled workers increases wages for unskilled workers and depresses those of skilled workers. Adding up both the externality and the supply effects reveals that an increase in the share of skilled workers has a non-linear influence on both the wages of skilled and unskilled workers

with this effect being unambiguously positive for unskilled workers and undetermined for wages of skilled workers. Unskilled workers benefit from an increase in the share of skilled workers through human capital externalities and through an increase of their relative scarcity. For skilled workers the effect of a positive supply shift depends on whether human capital externalities γ can overcompensate the negative neoclassical supply effect.

These findings provide the theoretical underpinning of our empirical analysis. Based on this model we formulate three hypotheses. We expect a) the regional density of human capital to have an effect on the wages of skilled and unskilled workers through the working of human capital externalities, b) the effect of human capital externalities to be of the same magnitude for skilled and unskilled workers, and c) supply shifts of skills to have a negative impact on the wages of skilled workers and a positive impact on those of unskilled workers. The model emphasizes the necessity to find an identification strategy which is able to disentangle the effects of human capital spillovers from those of supply shifts of skills. If not controlled for shifts in skills, human capital externalities are prone to be underestimated for skilled workers and overestimated for unskilled workers. The solution opted for here is to estimate the impact of regional capital on wages separately for skilled and unskilled workers employing an instrumental variable approach. The challenge is to find an instrumental variable which is related to the share of skilled individuals but is constant enough over time so as to not be related to shifts of skills (Angrist/Krueger 2001). We decide to use the local number of public schools and students attending them as instruments for the regional share of human capital. Before elaborating on the validity of these instruments we briefly outline alternative explanations for regional wage differentials which have been discussed in the literature and which partly shape our identification strategy.

II.2. Alternative Explanations for Regional Wage Differentials

Alternative theories on the development and the existence of regional wage differentials comprise increasing returns arising from economic density, as well as wage curve, amenity, and price level effects.

Arguments focusing on localized increasing returns to scale go back to Marshall (1890), who identifies labor market interactions, input-output linkages, and knowledge spillovers, the latter one being synonymous to technological externalities from human capital, as core mechanisms through which spatially bounded externalities come into existence (see Rosenthal/Strange 2004 for an overview).

Closely related to Marshall's early categorization, Duranton and Puga (2004) distinguish between matching, sharing, and learning mechanisms. Matching approaches are based on the idea that a large number of employers and employees in a regional labor market increases the chances of a high-quality match between workers and firms which in turn increases labor productivity. In sharing models spatial proximity to producers and to consumers allows firms to economize on transaction costs, which in turn leads to lower prices, increased demand, higher output, and higher wages. Both matching and sharing externalities are broadly regarded as arising from the mass of economic activity in general, rather than from the concentration of human capital. Since, however, the density of economic processes is prone to be correlated with the regional share of human capital we control for the regional extent of agglomeration in our empirical analysis.

Blanchflower/Oswald (1990) show empirically that with a doubling of unemployment average wages decrease by approximately ten percent, a finding since then known as the 'wage curve'. Notwithstanding the lack of an undisputed theoretical underpinning, this relation has been shown to hold to a different extent for practically all industrialized countries. With respect to Germany, Blien (2003) shows that a doubling of unemployment reduces wages by six percent. Since Südekum (2003) finds that unemployment tends to be lower in cities than in rural areas we are suspicious that unemployment might be correlated with regional human capital endowments and account for it in our subsequent analysis.

Roback (1982) was the first to show in a general equilibrium framework that regional amenities have an impact on wages and that the direction of this impact depends on whether these amenities are productive or not. Productive amenities by definition increase productivity and wages while non-productive amenities, in contrast, have a depressing effect on regional wages because workers having a preference for the respective amenity accept lower wages for being close to the amenity. Accordingly, Beeson (1991) empirically demonstrates that about forty percent of regional wage differentials in the US can be attributed to different amenity endowments. Whether or not land prices are a wage determining factor depends on the assumption of firm mobility. If firms display a lower mobility than workers they will compensate workers for higher land prices, since only by paying higher wages they can prevent workers from moving to places characterized by lower costs of living (Moretti 2004a). Firms are willing to compensate their workers for congestion as long as the costs of compensation are lower than the costs of relocation (Kim 2003). Yankow (2006) empirically shows that regional price levels have an ambiguous effect on wages. Brueckner/Thisse/Zenou (1999) demonstrate that the concentration of human capital increases with local amenities while Alonso-Villar (2002) shows that price levels are

closely linked to the share of skilled workers. We therefore decide to control for regional amenities and price levels in our analysis.

II.3. Identifying Human Capital Externalities

It is certainly true that “the principal challenge in any effort to estimate the effects of education on wages is identification” (Acemoglu/Angrist 2000: 2). The main obstacle to an exact identification of the size of externalities is the existence of unobservable wage determining factors on the individual, as well as on the regional level. In order to shed light on the impact of regional human capital externalities on wages we employ Mincerian individual wage equations augmented by regional wage determining factors. Individual wages are on the one hand determined by individual productivity relevant factors, all of which are familiar from a voluminous literature starting with the seminal works of Mincer (1974) and Becker (1975). In addition to individual factors we introduce aggregate variables to account for competing explanations of the urban wage premium outlined above. In its most general form the equation to be estimated reads

$$\log(w_{irt}) = X_{irt}\beta_k + \eta_1 D^{HQ} \times H_{rt} + \eta_2 D^{NHQ} \times H_{rt} + Z_{rt}\delta_j + \varphi U_{rt} + \tau P_{rt} + A_{rt}\lambda_m + d_{ir} + d_t + d_r + \varepsilon_{irt} \quad (7)$$

with w_{irt} denoting the wage of individual i in region r at time t and X_{irt} being individual productivity relevant criteria including age, sex, education, experience, and tenure. In order to examine our second hypothesis, i.e. whether regional human capital exerts the same effect on different types of workers, we interact the regional share of human capital H_{rt} with dummy variables according to whether individual i is highly qualified (D^{HQ}), or non-highly qualified (D^{NHQ}). Z_{rt} is a measure for regional agglomeration which controls for localized increasing returns arising from matching or sharing mechanisms outlined above. U_{rt} , P_{rt} and A_{rt} represent the regional unemployment rate, regional price levels, and the amount of regional amenities respectively. In order to control for unobservable effects we include d_{ir} , d_t and d_r as individual, time, and regional fixed effects. ε_{irt} is an error term with the usual properties.

Our primary goal is the correct identification of η_1 and η_2 in equation (7), which represent social returns to human capital. Our core identifying assumption is that no variable exists on a regional level which is correlated with the regional share of human capital, systematically influences individual wages, and is not included in the equation either directly or via an adequate proxy variable. The panel structure of the dataset enables us to control for unobserved heterogeneity on the individual as well

as on the regional level by including fixed effects. Fixed effects regression are, however, not able to account for supply and demand shifts of skilled and unskilled labor since these shifts are constant neither over time, nor within one entity.

In order to correctly identify the impact of human capital externalities on wages we use an instrumental variable approach (see Griliches/Hausman 1986). The instrumental variables used are inspired by Moretti (2004b), who uses the lagged city demographic structure and the number of land-grant colleges as instruments for regional human capital. We analogously resort to the idea that the future supply of highly-skilled workers is a valid instrument for today's regional human capital endowment. Based on this notion we employ the number of public schools in a region and the number of students attending them as instruments for the share of highly qualified workers. The intuition behind these instruments is that the number of public schools which qualify students for attending university, i.e. first and foremost Gymnasia (grammar schools), and the number of students attending them increases more than proportionally with regional density. This stems from the fact that not every city is able to maintain a Gymnasium, which means that children commute to larger cities in order to attend this type of schools. A substantial part of the students attending Gymnasia change to the university in the respective city after having finished school and later in life often start their first job there. The fact that highly qualified workers often attend higher education institutions in the city they went to public school in can partly be explained by the high degree of decentralization of universities and technical colleges in Germany. Since 139 of the 326 counties in Western Germany contain a university or a technical college it is easy for young people to stay close to their friends and family during school and university education and, later on, when starting their first job to stay in the city they already went to school in. Since the plausibility of this home-bias argument is mirrored in numerous contributions on the notoriously low mobility rates of German workers and students (see e.g. Haas 2002 and Hillmert 2004) we believe that the number of public schools and the students attending them are relevant instruments for the regional share of human capital. As for instrument exogeneity, it is hard to see why individual productivity should be influenced by the aggregate number of public schools or students. Various statistical tests in Section III confirm our intuition on instrumental relevance and exogeneity.

Some comments are in order with respect to the variables used in the analysis below. Our variable of interest, i.e. regional human capital endowment, is measured in four different ways. The preferred indicator for regional human capital is the share of highly qualified workers among the workforce within a region. Highly qualified workers are defined as those who hold a degree from a university or a technical

college.¹ The assumption underlying this variable is that productivity enhancing knowledge is to a large extent embodied in highly qualified people and from there radiates to the rest of the workforce via knowledge spillovers. The downside of using the share of highly qualified workers as an indicator of regional human capital is that it ignores the distribution of skills among the non-highly qualified. Since it is quite plausible that human capital externalities are not unique to the regional share of highly qualified workers but to the average level of education of the regional workforce, we introduce average education as an alternative measure of regional human capital. We construct this variable by assigning years of education to each type of formal degree and from these calculate average years of education in each region.² Finally, in order to investigate whether human capital externalities are rooted in the concentration of skills of a certain type we introduce the regional kurtosis of education and the Hirschman-Herfindahl index as measures for the intraregional distribution of human capital.

We use the absolute number of hotel beds per region as a proxy for a county's amenity endowment. Using hotel beds as a proxy for amenities addresses the problem that the majority of productive and unproductive amenities are not measurable and sometimes not even definable. The supply of hotel beds in a region indicates that it is attractive for people to travel into that region, be it out of leisure or business motives. The number of hotel beds is thus closely related to the idea of amenities, since their number expresses how attractive a place is for consumers or producers. Of course the use of one single variable impedes the disentangling of the respective impact of productive or unproductive amenities and the sign of that variable is therefore ambiguous, which is however of no relevance here.³

Congestion is proxied by the prices per square meter of sold land.⁴ We are not able to control for overall regional consumer prices since no such index exists on a county level. Land prices are an adequate proxy, though, since congestion unfolds price effects to a large extent through land prices. Secondly, land prices are the basis for the calculation of rents, which constitutes the most important item of average

¹ Technical colleges (*Fachhochschulen*) are supposed to be more practically oriented than universities and entry requirements are slightly below those for universities.

² Possible values are 'no formal education' (9 years), 'degree from Volks-/Haupt-/Realschule and subsequent vocational training' (13 years), 'Gymnasium without vocational training' (13 years), 'Gymnasium with vocational training' (16 years), 'degree from a technical college' (18 years), 'and university degree' (20 years).

³ We have refrained from weighting the number of hotel beds according to regional population since a weighting approach is subject to the assumption that unproductive amenities have a greater weight. This arises from the fact most natural amenities are located in sparsely populated places. Weighting hotel beds according to population would more than proportionally increase their weight. In addition, using the number of hotels per region instead of the number of hotel beds per region does not make much difference, since they show a correlation of .922.

⁴ We are using prices for sold land of all types, rather than prices for building land only since the data quality is much better; both types of land prices display a correlation of .967.

household expenditure. In accordance with DuMond/Hirsch/MacPherson (1999) we use land prices as a regressor on the right hand side rather than employing it to deflate wages, because the latter is subject to the unrealistic assumption that consumers do not adjust their buying or renting behaviour in the face of high prices or rents.

Finally, as pointed out by Moulton (1990), standard errors of regional variables are prone to be inflated, since regional variables are not assigned randomly to individuals. Therefore, all regressions are cluster corrected using Newey-West standard errors with the share of highly qualified workers being the cluster identifying variable (Newey/West 1987; Rogers 1993). Since the Newey-West procedure is much stricter than required by Moulton we do not run into danger of overestimating the impact of regional human capital on wages (Hoxby 2000).

III. Human Capital Externalities and Regional Wages

III.1. The Data

The data needed for the analysis is taken from four sources. Individual data on wages, education, experience and further controls are provided by the IAB employment sample, a two percent sample of all workers holding a job subject to social security contribution (see Drews 2007 and Hamann et al. 2004 for a comprehensive description of the data). From this spell data we construct a panel data set encompassing all observations made on the 30th of June each year. This annualized panel data set contains more than 18 million observations for Western Germany between 1975 and 2001. The definition of worker status along the lines of social security contributions excludes self-employed workers as well as public servants. One of the merits of the data set is its panel structure, which allows for tracking employment histories of workers over time. Another merit is that the data are very reliable since they provide the source for calculating social benefits entitlements, and employers are therefore obliged to submit them to the best of their knowledge. The flipside of data being generated from the employment register is that wages are top coded at the threshold of maximum social security payments.⁵

While other authors have often decided to ignore wages above this threshold and to employ a Tobit estimation strategy for censored data, we have imputed wages based

⁵ The ten percent of workers earning wages above this threshold, which increases from year to year, are free to choose to either pay the maximum amount of social security payments, or to leave the public system and insure privately.

on a strategy proposed by Gartner (2005), which predicts wages above the threshold from a full set of individual characteristics. Throughout the paper wages are defined as gross daily wages, which are inflation adjusted to the 2001 Euro level. The education variable in the dataset is a six-stage indicator, which contains information on a worker's highest degree of formal education. We have corrected for inefficient and inconsistent coding of the education variable using an improved variable provided by Fitzenberger/Osikominu/Völter (2006) and Drews (2006).

Part-time employees as well as apprentices and trainees are excluded from the data since their daily wages as well as the determinants of these wages are incommensurable to those of full time workers. From the remaining 13 million observations on about one million full time employees in Western Germany between 1977 and 2001 we draw a sample of ten percent of workers to keep the data computationally tractable.⁶ Drawing the sample and dropping the observations with missing relevant data leaves us with individual panel data containing 1,312,935 observations on 98,612 persons, which we have augmented by regional data from the German Federal Statistical Office from 1995 to 2001 provided via their online service GENESIS, by regional unemployment data provided by the Federal Employment Agency, and by information on regional population density provided by the Federal Office for Regional Planning.

These regional data are available at the level of the 326 counties (*Landkreise und kreisfreie Städte*) in Western Germany.⁷ The regional density variable is made up of a nine-stage indicator, which combines the density of the county with the population structure of the wider region a county is located in. A precise classification is provided in Table I. In the regression analysis the differentiability of the data on the location of a worker's workplace reduces from 326 to 267 counties, since in some cases small counties in the IAB dataset are either lumped together, or combined with core cities in order to impede decoding.

The descriptive evidence on individual wages in the next section covers the full period from 1977 to 2001; due to data constraints in the GENESIS data set we had to reduce the period of observation for the regression analyses to the years between 1995 and 2001, which leaves us with a set of 173,614 observations.

⁶ We have drawn a ten percent sample of workers and then added information on all available years for these draws; this way we have kept the panel structure of the data and can profit from it in the subsequent analyses.

⁷ Counties are equivalent to NUTSIII regions; they constitute the top-down fourth layer of a five-layer administrative system in Germany and are either made up by a single large city (*Kreisfreie Stadt*) or by an administrative unit of several smaller cities or towns (*Landkreise*).

III.2. Descriptive Evidence

Regionally augmented data on agglomeration, wages, and human capital reveal an astonishingly homogenous picture. Maps I and II show that economic activity in Germany conforms to Krugman's (1991) famous observation that "production is remarkably concentrated in space" (1991, p. 5). Map I is based on data provided by the Federal Statistical Office and contains the density of workers as measured by workers per square kilometer. Density ranges from below thirty to above 250 workers per square kilometer. Among the most densely populated areas are the cities of Munich, Stuttgart, Frankfurt, the Ruhr Area, and their respective neighboring counties. Sparsely populated counties are predominantly located in the northern part of Bavaria and in Eastern Germany. Data from the IAB sample reveal that more than 44 percent of all workers are employed in core cities above 100.000 inhabitants, which together comprise only five percent of the landmass, while about 16 percent work in rural counties, which together make up over 36 percent of the West German territory.⁸ These findings are in line with the regional density indicator in Map II.

Three insights emerge from Maps III and IV with respect to the spatial and temporal distribution of wages. Firstly, although Germany is characterized by a comparatively egalitarian overall wage structure, substantial regional differences in average wages exist. In 1975 average wages in the poorest quintile of regions used to be below 45 Euros, while average wages in the richest quintile were well above 52.50 Euros. In 2001 average wage in the poorest quintile of regions ranged below 75 Euros and in rich regions above 85 Euros. Secondly, wages are related to the underlying spatial structure inasmuch as they tend to be higher in agglomerated counties and lower in rural counties. Core cities like Munich, Stuttgart, Frankfurt, the Ruhr Area, Hannover and Hamburg displayed an average wage of above 86 Euros in 2001, while average wages in rural regions like Upper Franconia or the Emsland stood at 72 Euros. This adds up to a raw urban wage premium of 19.4 percent when comparing rural to urban regions. Thirdly, a comparison of Map III and Map IV reveals a stunning persistence of the regional distribution of high-wage and low-wage regions. After all, rich as well as poor regions have by and large kept their ranks over a period of 26 years. Turning to the dynamics of wages by type of region, Graph I shows that with the exception of the early 90s wages are monotonically growing; wages in all types of regions have at all times since 1975 followed the same pattern with wages in dense regions being always above those of peripheral regions. From this we suspect

⁸ We are referring to counties of density levels 1 and 5 here as defined by the Federal Office for Regional Planning and reproduced in Table I, both of which are defined as core cities above 100.000 inhabitants; population and areas of rural counties are calculated on the basis of county types 4, 7, and 9.

that while in general wages are determined in the same way in all types of regions, some factors, with human capital externalities being a prime candidate, have sustainably lifted wages in urban areas above those of rural regions.

Maps V and VI display regional human capital endowments as measured by the share of workforce holding a degree from a technical college or a university. The top quintile of regions is endowed with a share of highly qualified workers of above 25 percent, while the share of highly qualified regions in the lowest quintile of regions ranges below 4 percent. The distribution of human capital is highly unequal between urban and rural regions. The share of highly qualified workers ranges at 15 percent on average in core cities and is thus about 2.5 times larger than in rural regions, where it reaches an average of 6.6 percent. Turning to the dynamics of regional human capital, Graph II shows that while the share of highly qualified workers has been rising in all types of counties due to far ranging improvements in general education opportunities, this rise has been especially pronounced in counties of type 1, 2, and 5, i.e. in urban counties. These observations indicate that higher average wages in urban areas are to some extent driven by a larger share of highly qualified workers in cities compared to rural regions. However, ascribing differences in average regional wages exclusively to the sorting of measurable skills is insufficient since highly qualified workers in core cities earn 125 Euros, i.e. about 12 percent more than the 112 Euros earned by their equally well qualified colleagues in rural regions.

Summing up the evidence we conclude that, in accordance with numerous studies on regional development in industrialized countries, agglomeration of economic activity in German regions goes hand in hand with higher levels of wages and human capital. Descriptive evidence supports the notion that in addition to sorting effects human capital externalities may have a role to play as an explanation for regional wage differentials. The following regression analysis sheds light on the existence and the magnitude of human capital externalities as an explanatory factor for regional wage differentials while controlling for sorting effects and shifts of skills through fixed effects and instrumental variables.

III.3. Human Capital Externalities in OLS and Panel Estimates

Table II shows our results from OLS and panel estimation of equation (7). Column (I) contains OLS estimates for individual and regional determinants of individual wages excluding regional human capital. Since coefficients on individual characteristics are all in line with findings from a voluminous literature and do in principle not change between regressions we only briefly comment on them here. Age, gender, and experience all display the usual, nonlinear impact on wages, although the

coefficient of age is significant only in regressions containing individual fixed effects. As expected, private returns to education increase with degree of education. Female wages are by about twenty percent lower than men's wages and foreigners earn just about one percent more than natives all else equal. In contrast to individual characteristics, regional variables have a rather low explanatory power with respect to individual wages. In line with findings on the wage curve, regional unemployment significantly reduces wages. However, neither land prices nor amenities unfold an effect on wages. While coefficients on density have the expected sign, i.e. wages increase with the level of agglomeration, only one of them is statistically significant.

Introducing the regional share of highly qualified workers in Column (II) we find strong evidence for the existence of human capital externalities. Both coefficients of regional human capital are highly significant and an F-Test confirms their joint significance at the one percent level. The impact of regional human capital is, however, far larger for wages of highly qualified than for those of non-highly qualified workers; an increase in the regional share of highly qualified workers by one percent increases wages for highly qualified workers by .34 percent and by about .09 percent for non-highly qualified workers. A comparison of columns (I) and (II) shows that all other coefficients with the exception of those of the density variables remain largely unchanged. In line with our insights from the descriptive analysis, this observation points to a strong correlation between regional human capital and the extent of regional agglomeration. In column (III) we investigate whether regional human capital has a non-linear influence on wages as predicted by the model. The predictions from the model are not confirmed in our OLS estimates. In order to control for the sorting of workers along unobservable categories, we include individual fixed effects in columns (IV) and (V).

When controlling for workers' unobservable characteristics in a fixed effects model, the impact of human capital externalities on the wages of highly qualified workers increases to 1.1 percent while becoming insignificant with respect to wages of non-highly qualified workers. The finding that we have underestimated human capital externalities for highly qualified workers and overestimated them for non-highly qualified workers in OLS regressions is important in two respects. First of all, it tells us that the extent to which workers benefit from human capital externalities depends strongly on their characteristics. We think that it is useful in this context to interpret these unobservable characteristics as a worker's receptivity, i.e. as certain character traits which enable a worker to translate benefits from surrounding human capital endowments into own productivity enhancements. Secondly, our results show that sorting effects along unobservable characteristics go in opposite directions for highly

qualified and non-highly qualified workers, a finding we wish to leave for further research here. Our results from a cubic specification are exactly in line with our expectations from the theoretical model. With respect to the wages of highly qualified workers, the impact of human capital on wages reaches a local maximum with a share of highly qualified workers of 25 percent and displays a wage depressing effect beyond that value. The size of this effect appears reasonable to us since the share of highly qualified exceeds 25 percent in only about one fifth of the regions. In line with our expectations, regional human capital has an unambiguously positive effect on the wages of non-highly qualified workers.

Three conclusions emerge. As expected from our first hypothesis, human capital externalities have an impact on the wages of highly qualified as well as non-highly qualified workers. In addition, controlling for unobservable characteristics in panel regressions suggests that a worker's receptivity is an important determinant of the extent to which human capital externalities translate into benefits for workers through productivity enhancements. Our core insight from the panel analysis is that human capital externalities display a non-linear influence on wages of highly qualified and non-highly qualified workers which in accordance with our theoretical model we interpret as resulting from a combined influence of human capital externalities and neoclassical supply effects. In order to control for these supply effects we employ the instrumental variable approach outlined in the previous section.

III.4. Human Capital Externalities: An Instrumental Variable Approach

Although changes in wages caused by supply shifts are unlikely to be of substantial size within the short period of investigation between 1995 and 2001, we are suspicious that the coefficients of regional human capital partly capture the influence of regional shifts of skills and hence are not consistent estimates of the impact of human capital externalities. When testing for potential endogeneity of the share of highly qualified workers a test of seemingly unrelated regressions rejects the hypothesis of exogeneity at the ten percent level.⁹ Since we cannot rule out the possibility of endogeneity we employ the regional number of schools and the number of students attending them as instruments for regional human capital.

Statistical tests corroborate our theoretical intuition on instrumental relevance and instrumental exogeneity. The raw correlation of share of highly qualified workers per region with the number of public schools is .43, and with the number of students

⁹ We use a test of seemingly unrelated regressions since a common Hausman (1978) test is prone to under reject the hypothesis of exogeneity when used on clustered data (see Baum/Schaffer/Stillman 2003).

attending them .36. Our first stage estimates in table III(a) show that the coefficients of the instruments in our preferred cubic specification are all significant at the one percent level with an adjusted R^2 ranging above ninety percent. An F-test confirms their joint relevance at the one percent level. With respect to instrumental exogeneity, a J-test of overidentifying restrictions confirms that the hypothesis of exogeneity holds for both instruments at the one percent level. Since our theoretical considerations are corroborated by these statistical results we are confident that the regional number of schools and the students attending them are relevant and exogenous instruments for regional human capital endowments.

Table III(b) shows the results from the second stage regressions which include worker fixed effects as controls for unobserved heterogeneity of workers. Our suspicion that human capital externalities might be intertwined with supply shifts of highly skilled workers are confirmed by the data. Column (VIII) shows that all coefficients of regional human capital in a cubic specification are insignificant, which implies that our instrumental variable approach eliminates non-linearities arising from supply shifts of highly qualified workers.¹⁰ Using predicted values for regional human capital from our first stage we then estimate the influence of human capital externalities in a linear equation. Column (VII) shows that a rise in the regional share of highly qualified workers by one percent increases wages of highly qualified workers by nearly 1.8 percent, compared to .9 in the panel analysis without instruments. With respect to non-highly qualified workers, regional human capital externalities are slightly smaller with a one percent increase in regional human capital raising wages by .6 percent. Thus, while human capital externalities have a significant influence on wages of highly qualified and non-highly qualified workers alike, their impact is about three times larger for the former group. This finding not only runs counter to our expectation of an equal effect derived from the model, but also to Moretti's (2004b) finding for the US that wage effects from human capital externalities decrease with level of education. We suspect that collective wage agreements in Germany, which set wages for the majority of non-highly qualified workers but only for a minority of highly qualified workers, might suppress effects from regional human capital externalities on wages of non-highly qualified workers (see Haisken-DeNew/Schwarze 1997 on the educational scope of collective agreements).

¹⁰ In line with Kelejian (1971), Newey (1990), and Carroll et al. (2004) we have predicted the polynomials of the share of highly qualified workers from the same first stage specification we used for the non-exponential term.

III.5. Robustness Checks

In table IV we investigate whether our findings on the existence of human capital externalities hinge on our choice of the regional share of highly qualified workers as an indicator for regional human capital. We therefore rerun our OLS and panel regressions for alternative measures of regional human capital endowments, i.e. for regional average education, the regional kurtosis of education, and the regional Hirschman-Herfindahl index of education. As outlined above, each measure of regional human capital is subject to specific assumptions with respect to the sources of human capital externalities. While the regional share of highly qualified workers relates human capital externalities to workers with an academic degree, average education takes the overall level of schooling into account. Using the kurtosis and the Hirschman-Herfindahl index addresses the suspicion that human capital externalities are rooted in the concentration of workers with the same type of education.

Table IV shows that all indices identify strong human capital externalities for wages of highly qualified workers, but provide only very weak evidence of an effect of human capital externalities on wages of non-highly-qualified workers. These results from OLS and panel estimates are in line with our findings for the share of highly qualified workers as an index for regional human capital. The negative signs on the kurtosis and the Hirschman-Herfindahl index require a word of explanation. In our interpretation, both indices in practice measure the regional concentration of workers with a high school degree and subsequent vocational training, since these workers constitute about seventy percent of the German workforce. An increasing concentration of this type of workers in a regional workforce is strongly correlated with a decrease of highly qualified workers therein. The decidedly negative impact of the concentration measures might thus stem from a reduced share of highly qualified workers in the regional workforce, which indicates that this educational group, rather than the simple concentration of any other education type, is the underlying source of human capital externalities.

In order to control for supply shifts of skills we again employ our instrumental variable approach using the regional number of schools and of students as instruments. Table V and VI contain the first and second stage regressions. The set of first stage regressions indicates that the instruments are highly relevant for all our indicators. All instruments are significant at the one percent level in a cubic specification and F-tests strongly confirm their joint significance. The results from the second stage in table VI confirm the results from our previous analysis based on the regional share of highly qualified workers. Again, the coefficients of the impact of human capital externalities on the wages of highly qualified and non-highly qualified

workers substantially increase in size when we employ an instrumental variable approach. In line with previous results, human capital externalities are about three times larger for highly qualified than for non-highly qualified workers. Although this finding suggests that the impact of human capital externalities differs with respect to a worker's educational background we cannot rule out the possibility that this result is rooted in different processes of wage determination for highly qualified and non-highly qualified workers. Our findings also run counter to our second hypothesis from which we expected to find human capital externalities to be overestimated for non-highly qualified workers in OLS and panel regressions. Our results, in contrast, consistently show that human capital externalities are underestimated for highly qualified and non-highly qualified workers alike. This finding casts doubt on the assumption of imperfect substitutability between both types of workers being appropriate. Our findings rather suggest that highly qualified workers compete with both types of workers for jobs; thus, an increase of the number of highly qualified workers depresses wages of both types of workers alike, a finding which is reflected in our general underestimation of human capital externalities. Thus, non-highly qualified workers do not benefit from relative scarcity if the share of highly qualified workers increases due to competition between both groups; this notion is consistent with our lack of evidence for an overestimation of human capital externalities for either type of worker. This interpretation of our findings is in line with results from a broad literature on asymmetric substitutability between workers of different skill groups (see e.g. Katz/Murphy 1992).

Three basic insights emerge from employing alternative indicators of human capital with respect to human capital externalities, supply effects, and their respective importance for workers of different educational backgrounds. For all indicators of regional human capital we find strong evidence that human capital externalities matter for highly qualified and non-highly qualified workers alike, though we cannot say with certainty whether this impact is of equal size for both types of workers. Comparing our results from different indicators suggests that human capital externalities are first and foremost rooted in the extent to which a regional workforce is composed of highly-qualified workers, a finding which is in line with empirical insights for the United States. Finally, our finding that human capital externalities are underestimated for highly qualified and non-highly qualified workers alike makes us believe that in contrast to our theoretical model the elasticity of substitution between both types of workers is not symmetric. Rather, supply shifts of highly qualified workers depress wage of both types of workers alike, since highly qualified workers can substitute non-highly qualified workers and thereby eliminate the latter group's advantage from relative scarcity.

Our final robustness check is based on the possibility that other regional variables included in our analysis might have a differential impact on the wages of highly and non-highly qualified workers. Since in our specification we have not allowed these variables to exert different influences on different types of workers, we might have forced our human capital coefficients to take up group-specific influences from other regional variables. In order to account for this we split up unemployment, amenities, and land price levels into their respective impact on wages of highly and non-highly qualified workers and re-estimate our panel regressions. Table VII shows that the impact of human capital externalities remains unaltered for all indices. What we do observe, though, is that the coefficients of most other regional variables change considerably. Interestingly, unemployment unfolds a substantially higher impact on the wages of highly qualified than on the wages of non-highly qualified workers. While this observation calls for a deeper investigation of the wage curve differentiated by skill group, it also gives rise to the suspicion that the system of collective agreements protects wages of non-highly qualified workers from regional unemployment pressure, which is in line with our impression that it prevents their wages to fully adapt to productivity enhancing human capital externalities. While the role of land prices and amenities remains ambiguous, we now find strong evidence of regionalized increasing returns arising from the density of economic activity. We leave the question to which extent regional variables unfold a differential impact on different types of workers for future research and turn to our last exercise, i.e. an analysis on whether wages within regional industries shaped are to a different extent by human capital externalities.

IV. Human Capital Externalities by Industry

Microeconomic theory regards human capital externalities as being rooted either in processes of knowledge exchange between agents, or in firms' investment behavior with respect to physical capital. Since the importance of knowledge and physical capital varies widely between industries, the extent to which each industry provides a fertile soil for human capital externalities is likely to differ accordingly. In our analysis we have up to now treated human capital externalities as being independent of the type of industry they occur in. While we have of course controlled for the extent to which a worker's affiliation to an industry influences wages, for example through industry-wide collective agreements, by not differentiating human capital externalities by industry we have implicitly assumed that they unfold their impact unconditional on the industry a worker is employed in. However, Krueger/Summers'

(1988) finding of substantial wage differences between industries encourages an analysis on whether these are at least partly attributable to an inter-industry variance of human capital externalities (see Haisken-DeNew/Schmidt 1997 for inter-industry wage differentials in Germany). The remaining part of the paper therefore focuses on the extent to which the size of human capital externalities differs between industries.

With respect to workers' industry affiliation the data set enables us to differentiate between sixteen industries. We have rerun regression the panel regressions for the impact of regional human capital externalities on wages of highly qualified and non-highly qualified workers for each of the sixteen industries with and without instrumental variables. This leaves us with 32 results on sixteen industries contained in table VIII.

It turns out that in panel regressions without instruments the regional share of human capital has an impact on the wages of highly qualified workers in eleven out of sixteen industries. This impact always increases when we employ instrumental variables and becomes significant for all sixteen industries. Things are different when it comes to the impact of human capital externalities on the wages of non-highly qualified workers. In panel regressions we obtain only six significant coefficients, which further reduce to five when we employ instrumental variables. We do not find a clear pattern of changes in coefficient size between panel and instrument regressions. Even more puzzling is the occurrence of negative signs, as well as the frequent change of signs between panel and instrument regressions.

Our finding that within industries the effect from human capital externalities increases for highly qualified workers but is basically absent for non-highly qualified workers stands in stark contrast to our previous finding that regional human capital externalities affect both types of workers. However, the literature on the industrial scope of human capital externalities provides a suggestive explanation. In this literature, the debate on whether knowledge spillovers occur within industries or between them has a longstanding tradition. While adherents of Marshall-Arrow-Romer externalities contend that knowledge spillovers mainly arise through learning within industries (e.g. Wheaton/Lewis 2002), Jacobs (1961, 1969) and others argue that knowledge exchange between industries is more productivity enhancing than within industries. Our results indicate that the extent to which human capital externalities occur within or between industries is influenced by the educational background of workers. While we find within-industry human capital externalities to matter most for highly skilled workers, the impact of human capital externalities on the wages of non-highly qualified workers seems to work mainly through between-

industry effects. Our cautious guess is that our results are driven by different types of externalities being of prime importance for highly qualified and non-highly qualified workers. Thus, highly qualified workers first and foremost benefit from knowledge spillovers arising from frequent interaction with colleagues who are employed in the same industry. In this case, the intra-industry share of highly qualified workers is the frame of reference within which externalities evolve through communication and intellectual exchange. For non-highly qualified workers, in contrast, pecuniary externalities play a dominant role. Pecuniary externalities arise if firms invest in physical capital in anticipation of the qualification level of their future work force. It appears reasonable to assume that firms take overall regional human capital endowments rather than only regional human capital endowments within their own industry as a focal point when deciding on future investments. While the idea that pecuniary and technological human capital externalities differ in their different industrial scope and in their applicability to different types of workers is very well suited to explain our results, it certainly remains suggestive here. Both notions have to the best of our knowledge not yet been investigated in the theoretical and empirical literature and remain worthwhile objects of research.

Since the analysis reveals that within-industry human capital externalities have a highly significant impact on the wages of highly qualified workers in all industries, we focus on highly qualified workers in order to further investigate which industries are predominantly shaped by human capital externalities.

The range of social returns to human capital extends from 1.28 in Social Security Services to 6.66 in the Production of Consumption Goods. An increase of the share of highly qualified workers by one percent thus increases wages between one and nearly seven percent in our sixteen industries. The most ostensible finding emerging from table VIII is the clear division between manufacturing and services with respect to the size of externalities. The average magnitude of the wage effects of human capital spillovers amounts up to 4.25 percent in manufacturing, while it stands at 2.11 percent on average in services. A potential explanation relates to differences in knowledge and physical capital intensity between manufacturing and the service sector. We do not know from the data whether manufacturing or the service sector is more knowledge intensive and it is therefore impossible to tell whether knowledge spillovers are more pronounced in one of them. The issue is, however, more straightforward with respect to physical capital investments, which can reasonably be assumed to play a more far important role in manufacturing compared to the service sector. It is therefore likely that pecuniary externalities in manufacturing explain a large part of the difference to which human capital externalities occur in manufacturing and in the service sector. This finding encourages the development of

empirical methods as well as the generation of datasets which together are capable of discriminating between pecuniary and technological externalities, an undertaking we deem has not been followed thoroughly enough given the preliminary evidence on the substantial role this distinction has for the explanation of systematic differences in human capital externalities between workers and industries alike.

V. Conclusion

Regions in Western Germany differ remarkably with respect to their human capital endowments and average wage levels. Relying on a model of increasing social returns to human capital we have investigated the extent to which human capital externalities are a driving force behind regional wage differentials in Germany. Four insights have emerged.

Human capital externalities are an important wage determining factor. Employing the regional number of public schools and of students attending them as instruments for regional human capital endowments we find that the regional share of highly qualified workers increases wages by 1.8 percent for highly qualified workers and by .6 percent for non-highly qualified workers. This result is robust to the inclusion of a wide array of individual and regional variables, as well as individual and regional fixed effects. Employing alternative indicators for regional human capital endowments we demonstrate that human capital externalities are to a large extent rooted in the regional share of highly qualified workers.

Our instrumental variable approach enables us to disentangle the impact of human capital externalities on wages from that of supply shifts in human capital. We find human capital externalities to be underestimated by about fifty percent in simple panel regressions not only for highly qualified workers but, in contrast to our expectations, also for non-highly qualified workers. From this we infer that while an increase of the regional share of highly qualified workers depresses wages for both highly qualified and non-highly qualified workers alike due to a shared labor market, this neoclassical supply effect is overcompensated by human capital externalities impacting on the wages of both types of workers.

An investigation of regional human capital externalities by industry shows that highly qualified workers mainly benefit from intra-industry human capital externalities, while wages of non-highly qualified workers are more affected by human capital externalities occurring between industries. This finding indicates that knowledge externalities arising within industries through processes of learning are of greater importance for highly qualified workers than for non-highly qualified workers,

while the latter are predominantly affected by pecuniary externalities arising from firms' investment decisions based on overall regional human capital endowments.

The importance of the distinction between knowledge externalities and pecuniary externalities is corroborated by our finding that human capital externalities are on average fifty percent smaller in the service sector compared to manufacturing. While we cannot assess the relative size of knowledge externalities, greater physical capital endowments in manufacturing compared to service make us believe that pecuniary externalities are a driving force for the size difference in human capital externalities between both sectors.

Our finding of systematic differences of human capital externalities between educational groups, as well as between industries, should encourage research efforts in one main direction. Empirical insights into the microeconomic mechanics of human capital externalities are necessary in order to understand the relative magnitude of technological and pecuniary externalities and the ways through which they unfold benefits for different actors. Theoretical models in this field are far ahead of empirical insights and it remains to be hoped that the accessibility of new microeconomic datasets enables researches to shed further light on the mechanisms through which regional human capital and economic prosperity are connected. A promising example is provided by Jaffe (1989), who investigate the extent to which innovation is related to regional knowledge spillovers by using localized patent data.

The core message to policy makers arising from our findings is that regional human capital endowments have an important role to play for processes of regional development. The formation of an educated workforce should therefore be a core strategy of regional policy. However, two caveats apply, both of which touch on the issue of equality. Any policy being committed to increasing the share of highly qualified workers among its workforce should be aware that benefits from human capital externalities tend to more than proportionally accrue to highly qualified workers than to non-highly qualified workers. Thus, this type of regional policy might at least temporarily increase intraregional inequality and it depends on the extent to which the gains from higher productivity are passed on to non-highly qualified workers that the tide of human capital externalities lifts all boats. Secondly, it should be noted that highly qualified and non-highly qualified workers exhibit different propensities of migration with the former being more mobile than the latter. With rising wages in human capital intensive regions patterns of selective migration are prone to induce a process of interregional divergence. In a dynamic perspective an increasing spatial agglomeration of highly qualified workers in regions characterized by substantial human capital externalities will result in regional divergence and interregional inequality (see Südekum 2005). Such a process is hardly in line with the

German objective of establishing comparable standards of living in all regions (see Tetsch 1994). Any economic policy aiming to strike the balance between fostering prosperity through human capital externalities and promoting equality at the same time is therefore well advised to promote a regional concentration of human capital while at the same time “to increase the strength of the spread effects of the development impulses as between regions and between occupations” (Myrdal 1954: 81).

References

- Acemoglu, Daron 1996. A Micro-Foundation for Social Increasing Returns in Human Capital Accumulation. *Quarterly Journal of Economics* 111: 779-804.
- Acemoglu, Daron and Joshua Angrist. 2000. How Large Are Human Capital Externalities? Evidence from Compulsory Schooling Laws, in: Bernanke, Ben and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual*. Cambridge, MA: MIT Press.
- Alonso-Villar, Olga. 2002. Urban Agglomeration: Knowledge Spillovers and Product Diversity. *The Annals of Regional Science* 36: 551-73.
- Anastassova, Lubomira. 2006. Productivity Differences and Agglomeration Across Districts of Great Britain. *CERGE-EI Working Paper* 289. Charles University of Prague, Czech Republic.
- Angrist, Joshua and Alan B. Krueger. 2001. Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments. *Journal of Economic Perspectives* 15: 69-85.
- Arrow, Kenneth 1962. The Economic Implications of Learning by Doing. *The Review of Economic Studies* 29: 155-73.
- Baum, Christopher F., Mark E. Schaffer and Steven Stillmann. 2003. Instrumental Variables and GMM: Estimation and Testing. *The Stata Journal* 3: 1-31.
- Becker, Gary S. 1975. *Human Capital – A Theoretical and Empirical Analysis with Special Reference to Education*. Chicago: University of Chicago Press.
- Beeson, Patricia E. 1991. Amenities and Regional Differences in Returns to Worker Characteristics. *Journal of Urban Economics* 30: 224-41.
- Blanchflower, David G. and Andrew J. Oswald. 1990. The Wage Curve. *Scandinavian Journal of Economics* 92: 215-35.
- Blien, Uwe. 2003. Die Lohnkurve – Auswirkungen der regionalen Arbeitslosigkeit auf das Lohnniveau. *Mitteilungen aus der Arbeitsmarkt- und Berufsforschung* 4: 439-60.
- Brueckner, Jan K., Jacques F. Thisse and Yves Zenou. 1999. Why is Central Paris Rich and Downtown Detroit Poor? An Amenity Based Theory. *European Economic Review* 43: 91-107.
- Carroll, Raymond J., David Ruppert, Ciprian Crainiceanu, Tor Tosteson and Margaret Karagas. 2004. Nonlinear and Nonparametric Regression and Instrumental Variables. *Journal of the American Statistical Association* 99: 736-50.
- Ciccone, Antonio. 2002. Agglomeration Effects in Europe. *European Economic Review* 46: 213-28.
- Ciccone, Antonio and Robert Hall. 1996. Productivity and the Density of Economic Activity. *American Economic Review* 86: 54-70.
- Ciccone, Antonio and Giovanni Peri. 2006. Identifying Human Capital Externalities: Theory with Applications. *Review of Economic Studies* 73: 381-412.
- Combes, Pierre-Philippe, Gilles Duranton and Laurent Gobillon. 2008. Spatial Wage Disparities: Sorting Matters! *Journal of Urban Economics* 63: 723-42.
- Davies, Jim B. 2002. Empirical Evidence on Human Capital Externalities. *Working Paper* 2003-11, Department of Finance, Canada.
- Drews, Nils. 2006. Qualitätsverbesserung der Bildungsvariable in der IAB-Beschäftigtenstichprobe 1975 – 2001. *FDZ Methodenreport* 5. Federal Employment Agency, Nuremberg.

- Drews, Nils. 2007. Variablen der schwach anonymisierten Version der IAB-Beschäftigtenstichprobe 1975 – 2004. *FDZ Datenreport* 3/2007, Federal Employment Agency, Nuremberg.
- DuMond, J. Michael, Barry Hirsch and David A. MacPherson 1999. Wage Differentials Across Labor Markets and Workers: Does Cost of Living Matter? *Economic Inquiry* 37: 577-98.
- Duranton, Gilles and Diego Puga. 2004. Micro-foundations of Urban Agglomeration Economies; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Fitzenberger, Bernd, Aderonke Osikominu and Robert Völter. 2006. Imputation Rules to Improve the Education Variable in the IAB Employment Subsample. *Discussion Paper* No. 5, Center for Doctoral Studies in Economics and Management, University of Mannheim.
- Gartner, Hermann. 2005. The Imputation of Wages above the Contribution Limit with the German IAB Employment Sample. *FDZ Methodenreport* 2. Federal Employment Agency, Nuremberg.
- Glaeser, Edward L. and David C. Maré. 2001. Cities and Skills. *Journal of Labor Economics* 19: 316-42.
- Haas, Anette. 2002. Regionale Mobilität am Arbeitsmarkt: Wohin nach der Berufsausbildung? Die Ost/West-Mobilität von jungen Fachkräften. *IAB Kurzbericht* 07/2002.
- Haisken-DeNew, John P. and Christoph M. Schmidt. 1997. Interindustry and Interregional Differentials: Mechanics and Interpretation. *The Review of Economics and Statistics* 79: 516-21.
- Haisken-DeNew, John P. and Johannes Schwarze. 1997. Regionale Lohn disparitäten in Deutschland 1984-1994 – Eine Analyse mit regionalisierten Daten des Sozio-Ökonomischen Panels. *Informationen zur Raumentwicklung* 1/2: 51-61.
- Hamann, Silke, Gerhard Krug, Markus Köhler, Wolfgang Ludwig-Mayerhofer and Anne Hackett. 2004. Die IAB-Regionalstichprobe 1975 – 2001: IABS-R01. *ZA-Information* 55/2004.
- Hausman, Jerry A. 1978. Specification Tests in Econometrics. *Econometrica* 46: 1251-71.
- Hillmert, Steffen. 2004. Regional Mobility in Early Adulthood: the Impact of Qualifications. *Paper Prepared for the Annual Meeting of the European Research Network on Transition in Youth*, Nuremberg.
- Hirschman, Albert O. 1958. *The Strategy of Economic Development*. New Haven: Yale University Press.
- Hoxby, Caroline M. 2000. Does Competition among Public Schools Benefit Taxpayers? *American Economic Review* 90: 1209-38.
- Jacobs, Jane. 1961. *The Death and Life of Great American Cities*. New York: Random House.
- Jacobs, Jane. 1969. *The Economy of Cities*. New York: Random House.
- Jaffe, Adam B. 1989. Real Effects of Academic Research. *The American Economic Review* 79: 957-70.
- Kaldor, Nicholas. 1970. The Case for Regional Policies. *Scottish Journal of Political Economy* 17: 337-48.

- Kanbur, Ravi and Anthony J. Venables. 2005. Spatial Inequality and Development; in: Venables, Anthony J. (ed.) *Spatial Inequality and Development*. Oxford, London: Oxford University Press.
- Katz, Lawrence F. and Kevin M. Murphy. 1992. Changes in Relative Wages, 1963-87: Supply and Demand Factors. *Quarterly Journal of Economics* 107: 35-78.
- Kelejian, Harry H. 1971. Two-Stage Least Squares and Econometric Systems Linear in Parameters but Nonlinear in the Endogenous Variable. *Journal of the American Statistical Association* 66: 373-74.
- Kim, Bonggeun. 2004. The Wage Gap between Metropolitan and Non-metropolitan Areas. *Discussion Paper* 189, Australasian Meetings 2004, Econometric Society.
- Krueger, Alan B. and Larry H. Summers. 1988. Efficiency Wages and the Inter-Industry Wage Structure. *Econometrica* 56: 259-93.
- Krugman, Paul. 1991. *Geography and Trade*. Cambridge, MA: MIT Press.
- Kuznets, Simon. 1955. Economic Growth and Income Inequality. *The American Economic Review* 45: 1-28.
- Lehmer, Florian and Joachim Möller. 2009. Interrelations between the Urban Wage Premium and Firm-Size Wage Differentials: A Micro Data Cohort Analysis for Germany. Forthcoming: *Annals of Regional Science*.
- Lucas, Robert E. 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* 22: 3-42.
- Marshall, Alfred. 1890. *Principles of Economics*. London: Macmillan & Co.
- Mincer, Jacob. 1974. *Schooling, Experience and Earnings*. New York: NBER.
- Möller, Joachim and Anette Haas. 2003. The Agglomeration Differential Reconsidered: An Investigation with German Micro Data 1984-1997; in: Bröcker, Johannes, Dirk Dohse and Rüdiger Soltwedel (eds.). *Innovation Clusters and Interregional Competition*. Berlin: Springer.
- Moretti, Enrico. 2004a. Human Capital Externalities in Cities; in: Henderson, James V. and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Elsevier: San Diego, Oxford, London.
- Moretti, Enrico. 2004b. Estimation the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data. *Journal of Econometrics* 121: 175-212.
- Moulton, Brent R. 1990. An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units. *The Review of Economics and Statistics* 72: 334-38.
- Myrdal, Gunnar. 1957. *Economic Theory and Underdeveloped Regions*. New York: Ducksworth.
- Newey, Whitney K. 1990. Efficient Instrumental Variables Estimation of Nonlinear Models. *Econometrica* 58: 809-37.
- Newey, Whitney K. and Kenneth D. West. 1987. A Simple, Positive Semi-Definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix. *Econometrica* 55: 703-8.
- Rauch, James E. 1993. Productivity Gains from Geographic Concentration of Human Capital: Evidence from the Cities. *Journal of Urban Economics* 34: 380-400.
- Rogers, William. 1993. sg17: Regression Standard Errors in Clustered Samples. *Stata Technical Bulletin* 13: 19-23.

- Romer, Paul M. 1986. Increasing Returns and Long-Run Growth. *The Journal of Political Economy* 94: 1002-37.
- Rosenthal, Stuart S. and William C. Strange. 2004. Evidence on the Nature and Sources of Agglomeration Economies: in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Südekum, Jens. 2003. *Agglomeration and Regional Unemployment Disparities*. Frankfurt: Peter Lang.
- Südekum, Jens. 2005. The Pitfalls of Regional Education Policy. *FinanzArchiv* 61: 327-52.
- Südekum, Jens. 2008. Convergence of the Skill Composition across German Regions. *Regional Science and Urban Economics* 38: 148-59.
- Tetsch, Friedrich. 1994. 25 Jahre Gesetz über die Gemeinschaftsaufgabe 'Verbesserung der regionalen Wirtschaftsstruktur'; in: Blien, Uwe, Hayo Herrmann and Martin Koller (eds.) *Regionalentwicklung und regionale Arbeitsmarktpolitik – Konzepte zur Lösung regionaler Arbeitsmarktprobleme?* Nuremberg: Institute for Labor and Employment Research.
- Wheaton, William C. and Mark J. Lewis. 2002. Urban Wages and Labor Market Agglomeration. *Journal of Urban Economics* 51: 542-62.
- Yankow, Jeffrey J. 2006. Why Do Cities Pay More? An Empirical Examination of Some Competing Theories of the Urban Wage Premium. *Journal of Urban Economics* 60: 139-61.

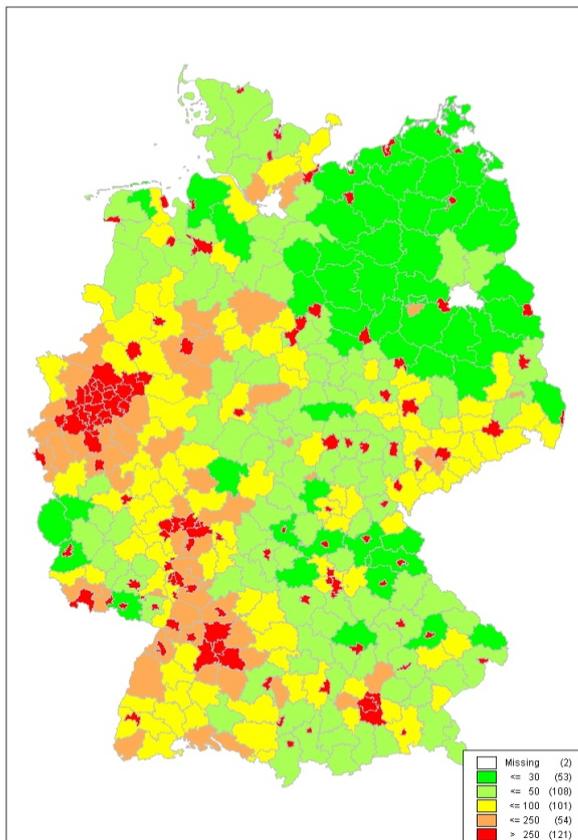
Appendix

Table I – Classification of Counties, Federal Office for Regional Planning

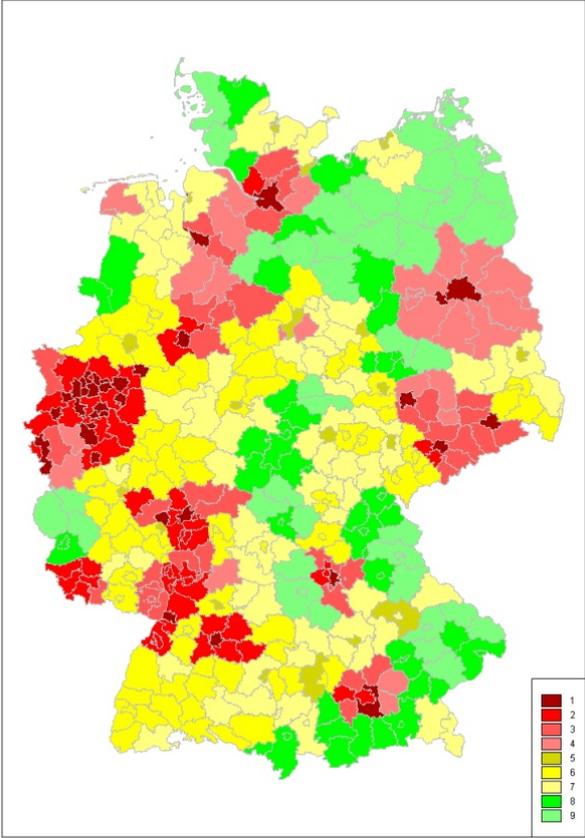
		Type of wider region a county is located in				
		Agglomerated Region		Slightly Agglomerated Region		Rural Region
Type of County	1	Core city in agglomerated region	5	Core city in slightly agglomerated area		
	2	Very dense county in agglomerated region				
	3	Dense county in agglomerated region	6	Dense county in slightly agglomerated region	8	Dense county in rural region
	4	Rural county in agglomerated region	7	Rural county in slightly agglomerated region	9	Rural county in rural region

Notes: Agglomerated Regions are classified as such by the existence of a core city with more than 300.000 inhabitants and/or by a population density of above 300 inhabitants per sqkm; Slightly Agglomerated Regions contain a core city with more than 100.000 inhabitants and/or are characterized by a population density above 150 inhabitants per sqkm; Rural Regions neither contain a core city of 100.000 inhabitants, nor does their population density exceed 150 inhabitants per sqkm.

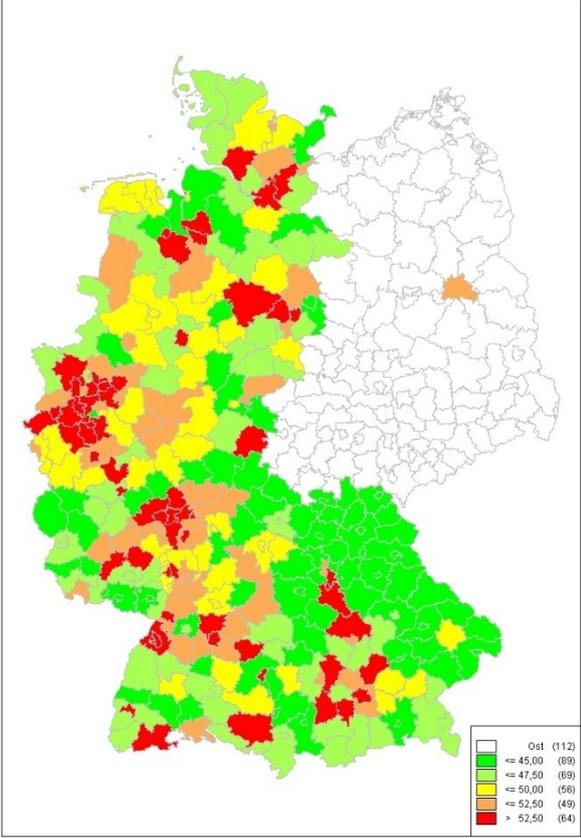
Map I – Number of Workers per sqkm by County, Average 2001



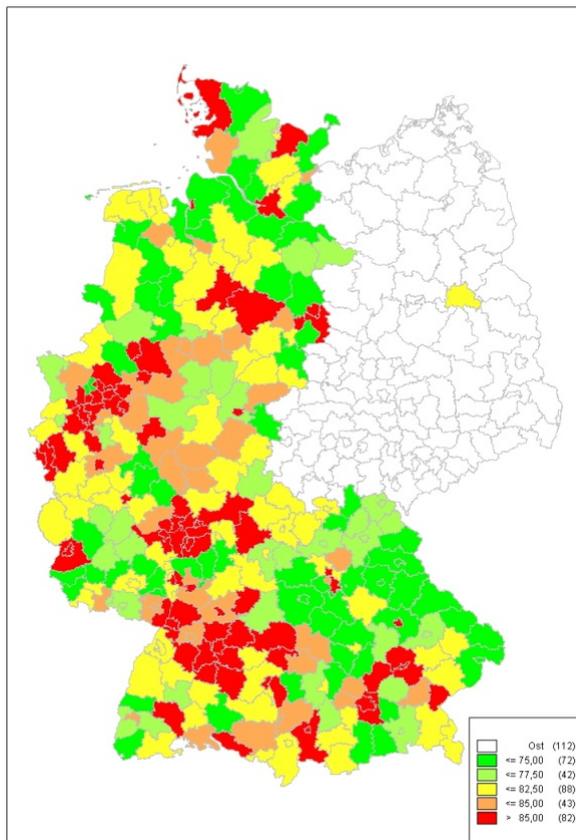
Map II – Regional Population Density, Indicator by the Federal Office for Regional Planning



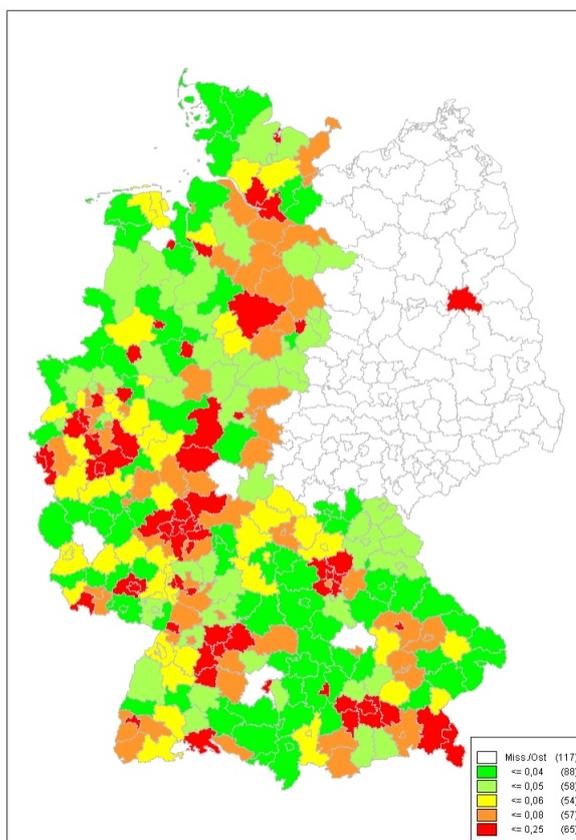
Map III – Daily Gross Wages by County, Averages 1975



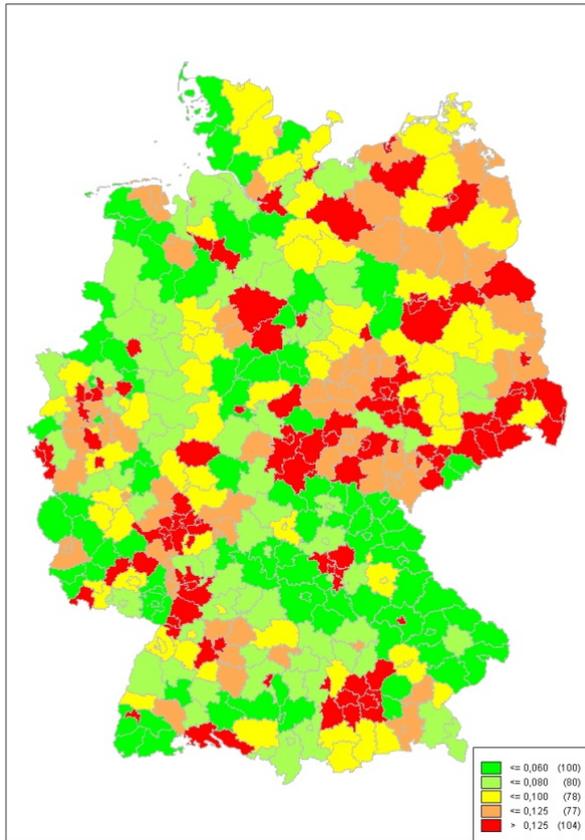
Map IV – Daily Gross Wages by County, Averages 2001



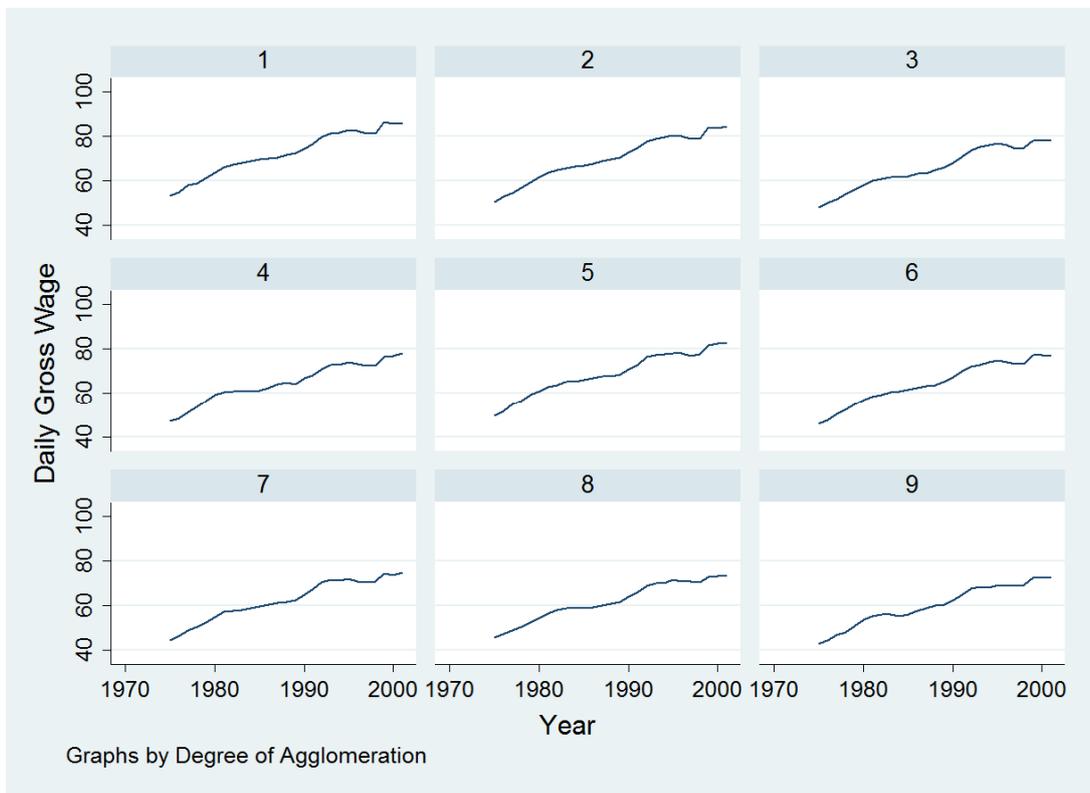
Map V - Educational Attainment by County, as % of Highly Qualified Workers, 1992



Map VI - Educational Attainment by County, as % of Highly Qualified Workers, 2001



Graph I – Dynamics of Daily Gross Wages (deflated), by Degree of Density



Graph II – Average Share of Highly Qualified Workers, by Degree of Density

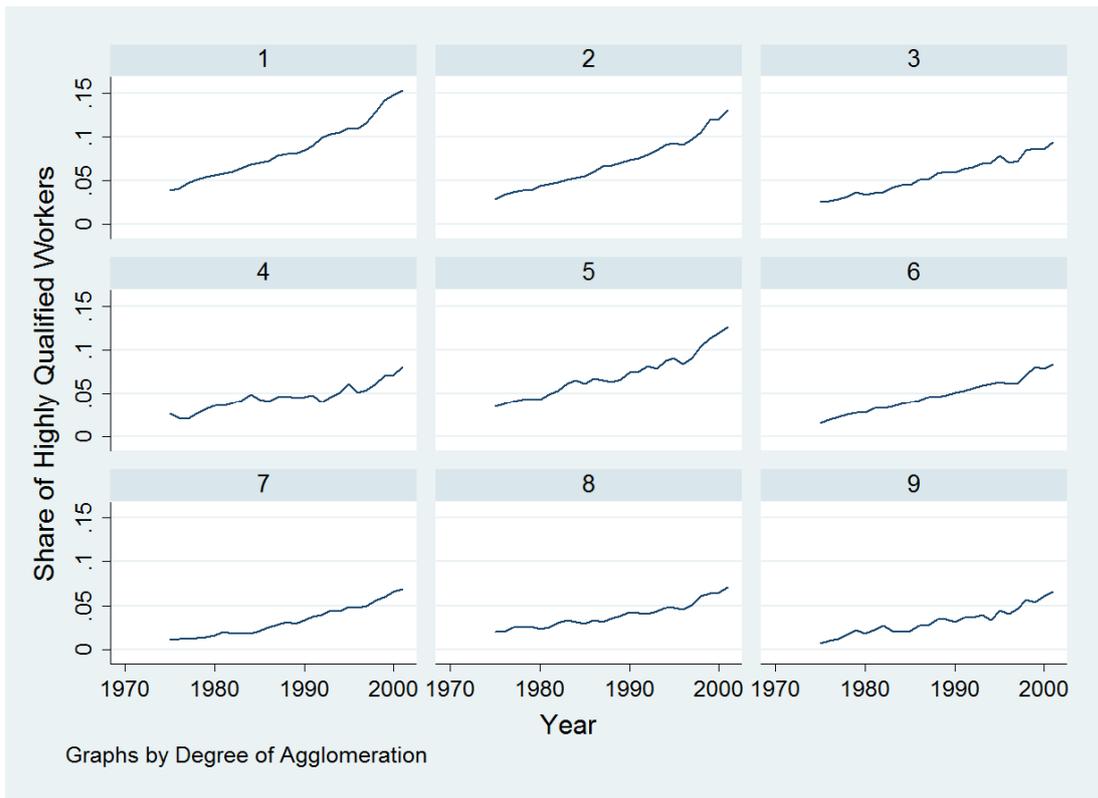


Table II – OLS and Panel Estimates

Dependent Variable: ln(wage _i)		(I)	(II)	(III)	(IV)	(V)
Individual Wage Determinants	Age	.001 (.0007)	.001 (.0007)	.001 (.0007)	.021 (.001)***	.021 (.001)***
	Age ²	-.00004 (.000008)***	-.00004 (.000008)***	-.00004 (.00008)***	-.0002 (.00001)***	-.0002 (.00001)***
	Sex	-.209 (.003)***	-.209 (.003)***	-.210 (.003)***	-	-
	Nation	.006 (.0005)***	.006 (.0005)***	.006 (.0005)***	-	-
	Tenure	.014 (.0004)***	.014 (.0004)***	.014 (.0004)***	.003 (.0004)***	.003 (.0004)***
	Tenure ²	-.0005 (.00002)***	-.0005 (.00002)***	-.0005 (.00002)***	-.0001 (.00002)***	-.0001 (.00002)***
	Experience	.023 (.0005)***	.023 (.0005)***	.023 (.0005)***	.009 (.0008)***	.009 (.0008)***
	Experience ²	-.0004 (.00002)***	-.0004 (.00002)***	-.0004 (.00002)***	-.0004 (.00002)***	-.0004 (.00002)***
	No Formal Degree	-.284 (.005)***	-.254 (.009)***	-.303 (.022)***	.015 (.017)	.014 (.017)
	V/H/R-Schule and Vocational Training Gymnasium	-.217 (.004)***	-.187 (.009)***	-.236 (.022)***	.048 (.017)***	.047 (.017)***
	Gymnasium and Vocational Training Technical College	-.171 (.010)***	-.140 (.013)***	-.189 (.024)***	Ref.	Ref.
	University	-.139 (.005)***	-.109 (.009)***	-.158 (.022)***	.099 (.016)***	.099 (.016)***
		Ref.	Ref.	Ref.	.086 (.019)***	.185 (.024)***
		.098 (.005)***	.095 (.005)***	.096 (.005)***	.177 (.019)***	.276 (.024)***
Regional Human Capital	Share HQ * D ^{HQ}	-	.339 (.072)***	-.942 (.583)*	.865 (.051)***	-1.50 (.380)***
	ShareHQ ² * D ^{HQ}	-	-	6.22 (4.53)	-	13.5 (2.71)***
	ShareHQ ³ * D ^{HQ}	-	-	-5.63 (10.4)	-	-20.6 (5.91)***
	Share HQ * D ^{NHQ}	-	.089 (.033)***	-.299 (.119)**	-.015 (.025)	-.289 (.092)***
	ShareHQ ² * D ^{NHQ}	-	-	2.52 (1.08)**	-	1.87 (.823)**
	ShareHQ ³ * D ^{NHQ}	-	-	-3.41 (2.94)	-	-2.68 (2.13)
Alternative Explanations for Urban Wage Premia	Unemployment Rate	-.003 (.001)***	-.003 (.001)***	-.003 (.001)***	-.004 (.001)***	-.004 (.001)***
	Land Price Level	-.002 (.002)	-.002 (.002)	-.003 (.002)	-.001 (.001)	-.002 (.002)
	Amenities	4.36*10 ⁻⁷ (1.52*10 ⁻⁷)	-2.43*10 ⁻⁷ (1.53*10 ⁻⁶)	-1.65*10 ⁻⁶ (1.04*10 ⁻⁶)	1.57*10 ⁻⁶ (.71*10 ⁻⁶)**	4.80*10 ⁻⁷ (7.31*10 ⁻⁷)
	Density 1	.040 (.080)	.005 (.072)	-.072 (.056)	.133 (.047)***	.123 (.047)***
	Density 2	.101 (.078)	.032 (.074)	-.076 (.066)	.079 (.053)	.080 (.053)
	Density 3	.066 (.081)	.032 (.073)	-.039 (.058)	.028 (.049)	.024 (.049)
	Density 4	.004 (.081)	-.031 (.073)	-.107 (-.056)	Ref.	Ref.
	Density 5	-.067 (.077)	-.101 (.069)	-.168 (.053)***	.093 (.055)*	.091 (.055)*
	Density 6	-.027 (.077)	-.066 (.070)	-.134 (.054)**	-.016 (.054)	-.023 (.054)
	Density 7	-.059 (.014)***	-.061 (.014)***	-.056 (.013)***	.069 (.067)	.058 (.067)
Density 8	.027 (.081)	-.017 (.074)	-.081 (.058)	-.106 (.054)**	-.105 (.054)**	
Density 9	Ref.	Ref.	Ref.	-.069 (.059)	-.026 (.060)	
Controls	Occupation Dummy	Yes	Yes	Yes	Yes	Yes
	Industry Dummy	Yes	Yes	Yes	Yes	Yes
	Year Dummy	Yes	Yes	Yes	Yes	Yes
	Region Dummy	Yes	Yes	Yes	Yes	Yes
	Worker Fixed Effects	No	No	No	Yes	Yes
	No. Observations	173,614	173,614	173,614	173,614	173,614
	No. Groups	-	-	-	39,758	39,758
	Prob(ShareHQ)=0	-	0.0000	0.0000	0.0000	0.0000
	Adj. R ² (overall)	.4795	.4796	.4797	.2849	.2849

Notes: All standard errors are cluster corrected by regional ShareHQ; standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; coefficients for constants are not reported here; variables *Sex* and *Nation* are dropped in panel regressions due to perfect multicollinearity with worker fixed effects; *Ref.* indicates reference category for dummy variables.

Table III(a) – IV-Estimates: First Stage

Dependent Variable: Share of HQ		(VI)
Individual Wage Determinants	Age	-
	Age ²	-
	Tenure	-
	Tenure ²	-
	Experience	-
	Experience ²	-
	No Formal Degree	-
	V/H/R-Schule and Vocational Training Gymnasium	-
	Gymnasium and Vocational Training Technical College	-
	University	-
	Instrumental Variables	No of Students
	No of Students ²	1.73*10 ⁻¹⁰ (3.40*10 ⁻¹²)***
	No of Students ³	-6.49*10 ⁻¹⁰ (1.61*10 ⁻¹⁷)***
	No of Secondary Schools	.002 (.00007)***
	No of Secondary Schools ²	-0.0001 (3.25*10 ⁻⁷)***
	No of Secondary Schools ³	1.49*10 ⁻⁸ (4.20*10 ⁻¹⁰)***
Exogenous Regional Variables	Unemployment Rate	-0.006 (.00008)***
	Land Price Level	.0007 (.0002)***
	Amenities	3.40*10 ⁻⁶ (7.97*10 ⁻⁸)***
	Density 1	.265 (.007)***
	Density 2	.078 (.009)***
	Density 3	.089 (.002)***
	Density 4	.061 (.002)***
	Density 5	.077 (.003)***
	Density 6	.090 (.002)***
	Density 7	.064 (.004)***
	Density 8	.171 (.002)***
Density 9	Ref.	
Controls	Occupation Dummy	No
	Industry Dummy	No
	Year Dummy	Yes
	Region Dummy	Yes
	Worker Fixed Effects	No
No. Observations	173,614	
Prob(Instr.=0)	0.0000	
Adj. R ²	.9167	

Table III(b) – IV-Estimates: Second Stage

Dependent Variable: ln(wage _i)			
		(VII)	(VIII)
Individual Wage Determinants	Age	.019 (.001)***	.019 (.002)***
	Age ²	-.0002 (.00001)***	-.0002 (.00001)***
	Tenure	.003 (.0004)***	.003 (.0004)***
	Tenure ²	-.0001 (.00002)***	-.0001 (.00002)***
	Experience	.009 (.0008)***	.009 (.0008)***
	Experience ²	-.0004 (.00002)***	-.0004 (.00002)***
	No Formal Degree	.013 (.017)	.013 (.017)
	V/H/R-Schule and Vocational Training Gymnasium	.046 (.017)***	.046 (.017)***
	Gymnasium and Vocational Training Technical College	Ref. (.099)	Ref. (.099)
	University	.139 (.019)***	.109 (.029)
	Regional Human Capital Predicted From 1 st Stage	Share HQ * D ^{HQ}	1.79 (.165)***
ShareHQ ² * D ^{HQ}		-	-5.17 (13.2)
ShareHQ ³ * D ^{HQ}		-	18.1 (28.6)
Share HQ * D ^{NHQ}		.601 (.157)***	-.378 (1.93)
ShareHQ ² * D ^{NHQ}		-	5.43 (12.5)
ShareHQ ³ * D ^{NHQ}		-	-9.16 (26.8)
Alternative Explanations for the Urban Wage Premium	Unemployment Rate	-0.003 (.0009)***	-0.003 (.0009)***
	Land Price Level	-.002 (.002)	-.002 (.002)
	Amenities	-1.17*10 ⁻⁶ (9.38*10 ⁻⁷)	-2.10*10 ⁻⁶ (1.33*10 ⁻⁶)
	Density 1	.138 (.047)***	.114 (.060)*
	Density 2	.058 (.053)	.060 (.054)
	Density 3	.028 (.049)	.017 (.052)
	Density 4	Ref.	Ref.
	Density 5	.075 (.054)	.077 (.056)
	Density 6	-.011 (.054)	-.025 (.058)
	Density 7	.085 (.067)	.082 (.068)
	Density 8	-.189 (.056)***	-.170 (.063)***
Density 9	.079 (.069)	.112 (.076)	
Controls	Occupation Dummy	Yes	Yes
	Industry Dummy	Yes	Yes
	Year Dummy	Yes	Yes
	Region Dummy	Yes	Yes
	Worker Fixed Effects	Yes	Yes
No. Observations	173,614	173,614	
No. Groups	39,758	39,758	
Adj. R ² (overall)	.2764	.2800	

Notes: All standard errors are cluster corrected by regional ShareHQ; standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; coefficients for constants are not reported here; First Stage Regression contains regional variables only; *Ref.* indicates reference category for dummy variables.

Table IV – OLS and Panel Estimates: Robustness Checks (I)

		Dependent Variable: ln(wage _i)					
		(IX)	(X)	(XI)	(XII)	(XIII)	(XIV)
Regional Human Capital	AvEducation * D ^{HQ}	.039 (.008)***	.108 (.006)***	-	-	-	-
	AvEducation * D ^{NHQ}	.005 (.004)	-.008 (.003)**	-	-	-	-
	Kurtosis * D ^{HQ}	-	-	-.003 (.001)***	-.010 (.0009)***	-	-
	Kurtosis * D ^{NHQ}	-	-	-.0001 (.0002)	.0003 (.0003)	-	-
	Herfindahl * D ^{HQ}	-	-	-	-	-.121 (.040)***	-.394 (.031)***
	Herfindahl * D ^{NHQ}	-	-	-	-	-.029 (.015)*	-.005 (.013)
Alternative Explanations for the Urban Wage Premium	Unemployment Rate	-.003 (.001)**	-.004 (.0009)***	-.003 (.001)**	-.004 (.0009)***	-.003 (.001)**	-.004 (.0009)***
	Land Price Level	-.003 (.002)	-.002 (.002)	-.002 (.003)	-.001 (.002)	-.002 (.003)	-.001 (.002)
	Amenities	-5.67*10 ⁻⁵ (1.42*10 ⁻⁶)	1.67*10 ⁻⁶ (.71*10 ⁻⁶)**	3.63*10 ⁻⁷ (1.51*10 ⁻⁶)	2.18*10 ⁻⁶ (.70*10 ⁻⁶)*	1.50*10 ⁻⁷ (1.47*10 ⁻⁶)	1.87*10 ⁻⁶ (.71*10 ⁻⁶)*
	Density 1	.016 (.075)	.129 (.047)***	.061 (.079)	.026 (.050)	.024 (.078)	.134 (.047)***
	Density 2	.062 (.076)	.079 (.053)	-.0004 (.084)	.093 (.055)*	.073 (.077)	.082 (.053)
	Density 3	.045 (.076)	.027 (.049)	-.031 (.079)	.043 (.053)	.052 (.079)	.026 (.049)
	Density 4	-.019 (.076)	Ref.	-.019 (.079)	-.112 (.054)**	-.013 (.079)	Ref.
	Density 5	-.088 (.072)	.089 (.054)*	.091 (.078)	.038 (.054)*	.074 (.077)	.092 (.054)*
	Density 6	-.051 (.073)	-.018 (.054)	-.008 (.080)	.008 (.061)	-.047 (.076)	-.013 (.054)
	Density 7	-.057 (.014)***	.057 (.067)	.028 (.075)	.093 (.069)	-.060 (.013)	.084 (.068)
	Density 8	-.0002 (.077)	-.078 (.054)	-.035 (.072)	-.075 (.058)	.009 (.079)***	-.093 (.054)
Density 9	Ref.	-.082 (.059)	Ref.	Ref.	Ref.	-.088 (.059)	
Controls	Occupation Dummy	Yes	Yes	Yes	Yes	Yes	Yes
	Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
	Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
	Region Dummy	Yes	Yes	Yes	Yes	Yes	Yes
	Worker Fixed Effects	No	Yes	No	Yes	No	Yes
No. Observations		173,614	173,614	173,614	173,614	173,614	173,614
No. Groups		-	39,758	-	39,756	-	39,758
Adj. R ² (overall)		.4796	.2840	.4794	.2850	.4795	.2847

Notes: Regressions are augmented by the familiar full set of determinants of individual productivity, which are not shown here since they display the expected usual properties; all standard errors are cluster corrected by regional ShareHQ; standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; coefficients for constants are not reported here; variables *Sex* and *Nation* are dropped in panel regressions due to perfect multicollinearity with worker fixed effects; *Ref.* indicates reference category for dummy variables.

Table V – IV Panel-Estimates: First Stage, Robustness Check

	Dependent Variable:	Average Level of Education	Kurtosis of Education	Herfindahl Index of Education
		(XX)	(XXI)	(XXII)
Instrumental Variables	No of Students	-0.00008 (.000002)***	.0004 (.00003)***	.00002 (.48*10 ⁻⁶)***
	No of Students ²	1.10*10 ⁻⁹ (.03*10 ⁻⁹)***	-9.40*10 ⁻⁹ (.37*10 ⁻⁹)***	-2.87*10 ⁻¹⁰ (.07*10 ⁻¹⁰)***
	No of Students ³	-3.91*10 ⁻¹⁵ (.13*10 ⁻¹⁵)***	4.22*10 ⁻¹⁴ (.18*10 ⁻¹⁴)***	1.04*10 ⁻¹⁵ (.03*10 ⁻¹⁵)***
	No of Secondary Schools	.012 (.0006)***	-.089 (.008)***	-.020 (.0001)***
	No of Secondary Schools ²	-.00006 (.000003)***	.0005 (.00003)***	.00001 (.000006)***
	No of Secondary Schools ³	8.69*10 ⁻⁸ (.34*10 ⁻⁸)***	-4.88*10 ⁻⁷ (.46*10 ⁻⁷)***	1.62*10 ⁻⁸ (.08*10 ⁻⁸)***
Controls	Regional Variables	Yes	Yes	Yes
	Year Dummy	Yes	Yes	Yes
	Region Dummy	Yes	Yes	Yes
	No. Observations	173,614	173,614	173,614
	Prob(Instr=0)	0.0000	0.0000	0.0000
	Adj. R ²	.9203	.8010	.9067

Notes: Standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; regressions contain the full set of regional variables familiar from Table III, which are not reported here.

Table VI – IV Panel-Estimates: Second Stage, Robustness Check

	Dependent Variable: ln(wage _{it})	(XXIII)	(XXIV)	(XXV)
	Regional Human Capital Predicted From 1 st Stage	Average Education * D ^{HQ}	.249 (.025)***	-
Average Education * D ^{NHQ}		.098 (.025)***	-	-
Kurtosis * D ^{HQ}		-	-.026 (.003)***	-
Kurtosis * D ^{NHQ}		-	-.006 (.003)	-
Herfindahl * D ^{HQ}		-	-	-.925 (.102)***
Herfindahl * D ^{NHQ}		-	-	-.384 (.097)***
Alternative Explanations for the Urban Wage Premium	Unemployment Rate	-.004 (.0009)***	-.003 (.001)***	-.002 (.001)**
	Land Price Level	-.005 (.002)***	-.002 (.002)	-.001 (.002)
	Amenities	1.45*10 ⁻⁶ (.96*10 ⁻⁶)	1.97*10 ⁻⁶ (.70*10 ⁻⁶)	0.06*10 ⁻⁷ (8.28*10 ⁻⁷)
	Density 1	-.056 (.048)	.127 (.047)***	.131 (.047)***
	Density 2	.036 (.054)	.073 (.053)	.100 (.053)*
	Density 3	-.0004 (.052)	.042 (.051)	-.004 (.049)
	Density 4	Ref.	Ref.	Ref.
	Density 5	.069 (.055)	.014 (.054)	.038 (.054)
	Density 6	-.025 (.057)	-.0009 (.054)	-.003 (.054)
	Density 7	.025 (.068)	.069 (.068)	.153 (.069)**
Density 8	-.102 (.054)*	-.153 (.054)***	-.162 (.055)***	
Density 9	.041 (.065)	.104 (.063)*	.024 (.065)	
Controls	Occupation Dummy	Yes	Yes	Yes
	Industry Dummy	Yes	Yes	Yes
	Year Dummy	Yes	Yes	Yes
	Region Dummy	Yes	Yes	Yes
	Worker Fixed Effects	Yes	Yes	Yes
	No. Observations	173,614	173,614	173,614
	No. Groups	39,758	39,758	39,758
	Adj. R ² (overall)	.2534	.2818	.2826

Notes: Regressions are augmented by the familiar full set of determinants of individual productivity, which are not shown here since they display the expected usual properties; standard errors are cluster corrected by regional ShareHQ; standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; coefficients for constants are not reported here; *Ref.* indicates reference category for dummy variables.

Table VII – Panel Estimates, Robustness Checks (II)

		Dependent Variable: $\ln(\text{wage}_i)$				
		(XV)	(XVI)	(XVII)	(XVIII)	(XIX)
Alternative Measures of Regional Human Capital	Share HQ * HQ	.702 (.057)***	-1.39 (.384)***	-	-	-
	ShareHQ ² *HQ	-	12.85 (2.76)***	-	-	-
	ShareHQ ³ *HQ	-	-21.72 (6.01)***	-	-	-
	Share HQ*NHQ	-.0007 (.025)	-.277 (.092)***	-	-	-
	ShareHQ ² *NHQ	-	1.73 (.824)**	-	-	-
	ShareHQ ³ *NHQ	-	-2.10 (2.13)	-	-	-
	AvEducation * D ^{HQ}	-	-	.094 (.007)***	-	-
	AvEducation*D ^{NHQ}	-	-	-.007 (.003)**	-	-
	Kurtosis*HQ	-	-	-	-.007 (.001)***	-
	Kurtosis*NHQ	-	-	-	.0002 (.0002)	-
	Herfindahl*HQ	-	-	-	-	-.292 (.034)***
	Herfindahl*NHQ	-	-	-	-	-.011 (.013)
	Alternative Explanations for Urban Wage Premia	Unemployment Rate * D ^{HQ}	-.017 (.001)***	-.016 (.001)***	-.017 (.001)***	-.019 (.001)***
Unemployment Rate * D ^{NHQ}		-.002 (.0009)***	-.002 (.0009)***	-.002 (.0009)***	-.002 (.0009)***	-.002 (.0009)***
Land Price Level * D ^{HQ}		.004 (.004)	.003 (.004)	-.0004 (.004)	.012 (.004)***	.010 (.004)***
Land Price Level * D ^{NHQ}		-.003 (.001)	-.003 (.002)	-.002 (.002)	-.004 (.002)**	-.003 (.002)**
Amenities * D ^{HQ}		1.01*10 ⁻⁶ (.78*10 ⁻⁶)	-.23*10 ⁻⁶ (.79*10 ⁻⁶)	-1.06*10 ⁻⁶ (.77*10 ⁻⁶)	1.85*10 ⁻⁶ (.77*10 ⁻⁶)**	1.43*10 ⁻⁶ (.77*10 ⁻⁶)*
Amenities * D ^{NHQ}		1.41*10 ⁻⁶ (.71*10 ⁻⁶)	.40*10 ⁻⁶ (.73*10 ⁻⁶)	1.51*10 ⁻⁶ (.71*10 ⁻⁶)**	1.77*10 ⁻⁶ (.71*10 ⁻⁶)**	1.56*10 ⁻⁶ (.71*10 ⁻⁶)**
Density 1		.262 (.046)***	.254 (.046)***	.259 (.046)***	.038 (.047)	.261 (.047)***
Density 2		.209 (.052)***	.209 (.052)***	.209 (.052)***	.108 (.053)**	.209 (.053)***
Density 3		.148 (.049)***	.145 (.049)***	.147 (.049)***	.046 (.049)	.142 (.049)***
Density 4		Ref.	Ref.	Ref.	Ref.	Ref.
Density 5		.223 (.053)***	.222 (.053)***	.220 (.053)***	.124 (.055)**	.219 (.054)***
Density 6		.102 (.054)*	.097 (.054)*	.101 (.054)*	.013 (.057)	.099 (.054)*
Density 7		.192 (.067)***	.185 (.067)***	.181 (.067)***	.104 (.068)	.204 (.067)***
Density 8	.014 (.055)	.013 (.055)	.038 (.055)	-.073 (.054)	.021 (.054)	
Density 9	.060 (.058)	.103 (.059)*	.049 (.058)	-.068 (.059)	.044 (.058)	
Controls	Determinants of Individual Productivity	Yes	Yes	Yes	Yes	Yes
	Occupation Dummy	Yes	Yes	Yes	Yes	Yes
	Industry Dummy	Yes	Yes	Yes	Yes	Yes
	Year Dummy	Yes	Yes	Yes	Yes	Yes
	Region Dummy	Yes	Yes	Yes	Yes	Yes
	Worker Fixed Effects	Yes	Yes	Yes	Yes	Yes
	No. Observations	173,614	173,614	173,614	173,585	173,614
	No. Groups	39,758	39,758	39,758	39,756	39,758
	Adj. R ² (overall)	.2833	.2836	.2835	.2829	.2828

Notes: Regressions are augmented by the familiar full set of determinants of individual productivity, which are not shown here since they display the expected usual properties; all standard errors are cluster corrected by regional ShareHQ; standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; coefficients for constants are not reported here; *Ref.* indicates reference category for dummy variables.

Table VIII – Panel and IV(Second Stage) - Estimates by Industry

Dependent Variable: ln(wage _i); West Germany								
	(XXVI)		(XXVII)		(XXVIII)		(XXIX)	
	Agriculture		Production of Raw Materials		Production of Primary Investment Goods		Production of Secondary Investment Goods	
	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV
Share HQ*HQ	.459 (.45)	3.90 (1.2)***	1.22 (.23)***	4.57 (.64)***	.968 (.221)***	3.16 (.63)***	1.28 (.21)***	2.13 (.68)***
Share HQ*NHQ	-.331 (.16)**	-.309 (.87)	-.157 (.08)**	.642 (.52)	-.054 (.08)	-.112 (.53)	.055 (.09)	.267 (.62)

	(XXX)		(XXXI)		(XXXII)		(XXXIII)	
	Production of Consumption Goods		Food Production and Processing		Construction, Primary		Construction, Secondary	
	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV
Share HQ*HQ	1.05 (.32)***	6.66 (.85)***	.433 (.44)	4.29 (1.1)***	1.97 (.31)***	3.52 (.72)***	.709 (.52)	3.14 (1.3)**
Share HQ*NHQ	-.151 (.07)**	.619 (.52)	.085 (.09)	-1.37 (.62)**	-.106 (.09)	.515 (.59)	.187 (.10)*	1.31 (.65)**

	(XXXIV)		(XXXV)		(XXXVI)		(XXXVII)	
	Distribution Services (I)		Distribution Services (II)		Transport and Information Services		Industry Services	
	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV
Share HQ*HQ	1.39 (.27)***	2.90 (.76)***	.401 (.40)	1.48 (.79)*	.781 (.41)*	2.59 (.79)***	1.24 (.16)***	1.78 (.61)***
Share HQ*NHQ	-.173 (.11)	-.133 (.65)	-.110 (.09)	1.02 (.60)*	-.022 (.09)	.278 (.55)	-.129 (.10)	-.142 (.59)

	(XXXVIII)		(XXXIX)		(XL)		(XLI)	
	Consumer Services		Society Services (I)		Society Services (II)		Social Security	
	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV	Panel	Panel-IV
Share HQ*HQ	1.56 (.37)***	4.03 (.97)***	.854 (.14)***	2.07 (.49)***	.496 (.195)**	1.50 (.62)**	.069 (.15)	1.28 (.46)***
Share HQ*NHQ	-.077 (.13)	.852 (.84)	-.195 (.07)***	-.764 (.46)*	-.287 (.09)***	-.149 (.56)	.021 (.06)	-.181 (.38)**

Notes: All regressions are panel regressions on individual gross daily wage, augmented by the familiar full set of individual and regional determinants of productivity as well as by density, occupation, industry, year, region and worker fixed effects, all of which are not shown here since they display the expected usual properties; standard errors are cluster corrected by regional ShareHQ; standard errors in parentheses; ***, ** and * indicate significance at the 1% level, the 5% level and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors for *Amenities* are divided by 10⁻⁶.

Career Networks and Job Matching - Evidence on the Microeconomic Foundations of Human Capital Externalities

Abstract

Inspired by the literature on the importance of local career networks for the quality of labor market matches we investigate whether human capital externalities arise from higher job matching efficiency in skilled regions. Using two samples of highly qualified workers in Germany, we find that increasing the regional share of highly qualified workers by one standard deviation raises wages on the incidence of job change by up to three percent, pointing to the importance of improved job matching opportunities in human capital rich regions as a microeconomic source of human capital externalities. Evidence on regional differences in job change behavior suggests that human capital networks enable young workers to change jobs more easily and to thereby increase matching efficiency, which in turn reduces the overall number of job changes needed until an efficient match is reached. Benefits from improved matching opportunities predominantly arise from human capital networks enabling workers in skilled regions to change jobs within an industry and, thus, to capitalize on their industry-specific human capital.

Keywords: Human Capital Externalities, Job Matching, Agglomeration Economies
JEL Categories: D62, J24, J31, R11

I. Introduction – The Microeconomics of Human Capital Externalities

“Put differently, it is now time to [...] attempt to understand precisely how human capital externalities percolate. [...] Most mechanisms generating local increasing returns to scale can be enriched to take human capital into account and generate external effects of human capital”.

Gilles Duranton (2006: 35)

The idea that aggregate human capital matters for productivity and growth, which has gained prominence with the seminal contribution by Lucas (1988), has over time been established as one of the empirical regularities in economics. While early macroeconomic studies show that economic growth increases with national average levels of education, more recent investigations on the matter have predominantly come from urban and regional economics. In this branch, empirical studies by Rauch (1993), Moretti (2004b), and Rosenthal/Strange (2008) provide robust evidence that aggregate regional education positively influences individual productivity and wages.¹

Despite providing compelling evidence that regional human capital contributes to higher individual wages, none of the regional studies explicitly addresses the microeconomic mechanisms through which productivity enhancing effects from aggregate education come about.² This striking neglect can only be understood in historical perspective, i.e. when taking into account that from Marshall (1890) onwards external effects from aggregate education have routinely been assigned to spillovers of technological knowledge. Thus, in line with the notion that “the mysteries of the trade become no mysteries but are, as it were, in the air” (Marshall 1890: 271), a number of microeconomic papers have modeled the intensity of knowledge exchange as a function of local human capital (see Jovanovic/Rob 1989, Jovanovic/Nyarko 1995, and Black/Henderson 1999). Based on the prominence of the concept of knowledge spillovers, numerous empirical papers have investigated the importance of spatial proximity of human capital for regional innovation and growth. For a survey of this literature we refer the reader to Audretsch/Feldman (2004).

Without denying the importance of spillovers of technological knowledge as a source of human capital externalities, Gilles Duranton emphasizes in the opening quote that there might be more to human capital externalities and in this respect points to the richness of microeconomic mechanisms of agglomeration as a source of inspiration.

¹ The relationship between aggregate human capital and employment growth has been investigated e.g. by Simon/Nardinelli (2002) and Glaeser/Shapiro (2003). For reasons of brevity we refer the reader to Davies (2002) and Moretti (2004a), who survey the empirical literature on human capital externalities.

² Although human capital externalities are likely to also emerge as non-market externalities like reduced crime, or improved health or voting behavior, in what follows we restrict ourselves to a discussion of the microeconomic sources of market externalities and their relative importance.

Since the influential contribution by Duranton/Puga (2004), such microeconomic sources of agglomeration are usually categorized along the lines of sharing, matching, and learning, as core mechanisms through which increasing returns to scale from agglomeration contribute to higher wages in urban areas. Theories relying on sharing mechanisms suggest that firms in agglomerated areas benefit from sharing larger local markets with suppliers and customers alike, which in turn allows them to economize on transport costs and, hence, be more productive.³ Theories of matching, in contrast, model benefits from agglomeration as being rooted in improved matching opportunities between workers and firms in dense urban areas (Kim 1990, Helsley/Strange 1990). Based on this taxonomy a number of studies have aimed to disentangle the sources of agglomeration economies as determinants of regional wages (see e.g. Glaeser/Maré 2001, Yankow 2006, and Wheeler 2006). In contrast, no such attempt has been made with respect to human capital, i.e. apart from evidence on the existence of localized knowledge spillovers not much is known about the mechanisms through which human capital externalities emerge.⁴ This lack of knowledge about the microeconomic foundations of human capital externalities is startling since benefits from human capital externalities can, in principle, rest on a rich subset of microeconomic mechanisms similar to those underlying agglomeration externalities, i.e. on improved opportunities for learning, sharing, and matching.

Recognizing the lack of research on the microeconomic foundations of human capital externalities this paper investigates the role of improved matching opportunities arising from higher levels of aggregate education. Closely related to the literature on knowledge spillovers, the idea is that higher levels of education enhance the flow of information on job and career opportunities and thereby improve the quality of labor market matches in human capital rich regions. The fundamental difference between the literature on knowledge spillovers and the idea pursued here is that while the former literature regards knowledge as being of a purely technological nature, i.e. to entail information about products and process of production, we investigate whether increased levels of human capital carry information about vacancies, jobs, and careers, i.e. about efficient future matches between workers and firms. The idea that higher levels of overall education facilitate the flow of labor market information is intimately linked to the notion of career networks. Thus, a large body of sociological literature starting with Fischer (1982) has emphasized the importance of individual education for the size of social networks and therefore for access to informal information. This literature consistently finds that “the more educated people are, the

³ New Economic Geography models are the most prominent type of models in this category. See Ottaviano/Thisse (2004) for an overview.

⁴ See Halfdanarson/Heuermann/Südekum (2008) for a comparison of the empirical literatures on the urban wage premium and on human capital externalities.

larger their personal network” (Grossetti 2007: 397). This finding implies that the size of networks not only depends on a worker’s own human capital. In fact, the range of direct and indirect contacts within networks and thereby the amount of information accessible to an agent crucially depends on the surrounding overall level of education. Thus, human capital externalities may arise not only from the diffusion of technological knowledge between agents, but also from the transmission of information on job market opportunities and career perspectives, which over time leads to more efficient job matches.

The insight that career networks matter for the incidence of job changes and for the quality of job matches is rooted in the influential contribution by Granovetter (1974), who shows that more than fifty percent of job changers have found their job through personal contacts. Subsequent research on the structure of career networks has shown that they typically exhibit two properties, which are important for our own study. First, as shown by Boorman (1975), Granovetter (1983), and Podolny/Baron (1997), career networks transmit information most efficiently if they consist of many ‘weak’ ties, i.e. if a large number of individuals are loosely connected to each other. Such networks structures are contrasted to those made up by a small number of strong ties, e.g. close friends and kinship. Second, efficient career networks are characterized by a pronounced local dimension. In fact, models from information science (Cowan/Jonard 2004) and epidemiology (Jeger et al. 2007) show that information is transmitted most efficiently in networks exhibiting distinct small world structures, meaning that about ninety percent of contacts are regionalized, while the rest are of a long-distance nature. Accordingly, Casper/Murray (2005) provide evidence on the regionalization of information flows by showing that career paths of highly qualified workers within biotechnology clusters in Cambridge, UK, and in Munich, Germany, are shaped through participation in strongly localized career networks.

In sum, our study sets out from the idea that regional human capital endowments shape the size of local career networks and thereby determine the amount of information available to workers about job and career opportunities. The availability of such information in turn influences the efficiency of job matches within local labor markets. Theoretically, differences in local matching efficiency should be reflected in wage gains incurred by job changers, and in the job change behavior of workers over their life cycle. Concretely, workers who have access to larger career networks in skilled regions are more likely to change jobs early in life since knowledge on job opportunities allows them to earn higher wages by changing to a job where they can be more productive. Consequently, given their knowledge about efficient job matches, they can be expected to incur larger wage gains on the incidence of job changes than

workers in regions with low human capital endowments, who have less access to information on prospective career options. In general, workers ‘shop between jobs’ until they have found an efficient job match (Mincer/Jovanovic 1981, Farber 1999). Therefore, since workers in skilled regions find efficient job matches earlier in life, their propensity to change jobs should decrease faster than the propensity of workers in unskilled regions.

Putting this matching concept of human capital externalities to the test, we examine whether we can find empirical support for the two hypotheses arising from economic theory. First, with the existence of matching externalities, we expect to find workers in human capital rich regions to incur larger wage gains when changing jobs than workers in unskilled regions. Secondly, we expect to find workers in human capital rich regions to be more likely to change jobs earlier in life, but to display a smaller overall number of job changes. Using two panels of highly qualified workers, we first estimate Mincerian wage equations in order to investigate whether wage gains incurred by job changers are positively influenced by the regional level of human capital. Addressing the second hypothesis, we analyze whether regional human capital endowments increase the probability of a job change early in a worker’s life, while depressing the overall number of job changes over the life cycle.

Our findings suggest that improved matching opportunities in skilled regions are of importance as a microeconomic source of human capital externalities. We find that an increase in the regional share of human capital by one standard deviation is associated with between-job wage growth of about two to three percent. Furthermore, an increase in the regional share of human capital by one standard deviation increases the annual probability of a job change early in life by up to .5 percent. Conversely, the total number of job moves is significantly and negatively related to the regional level of human capital. These findings together provide strong evidence that job matching efficiency is higher in human capital rich regions. Differentiating our results by types of job change, i.e. whether job changes occur within or between industries, we gain insight into the information content of career networks. Thus, we find that workers in human capital rich regions are about fifty percent more likely to change jobs within an industry rather than changing into a different sector. In addition, wage effects from aggregate human capital are about ten times larger for workers changing jobs within an industry compared to changers to other sectors. These findings suggest that the bulk of benefits from career networks arise because such networks allow young workers to obtain information on career options within industries and thereby to capitalize on their industry-specific human capital acquired earlier in life.

II. Social Networks and Job Matching: Literature Review and Econometric Approach

II.1. Local Career Networks and Job Matching Opportunities: Assumptions

In order for regional aggregate education to have an impact on the quality of labor market matching through more efficient information flows in local career networks, three premises have to be met. We briefly outline the rationale behind each of these premises and present empirical evidence on the extent to which they apply.

First and most crucial, our investigation hinges on the assumption that the quality of labor market matches is positively influenced by the existence and, more specifically, the size of career networks. Implicitly, such networks are assumed to reduce information gaps by providing informal information to workers and firms about unobservable characteristics of the other party (Jovanovic 1979). The intuition that career networks improve the quality of job matches has inspired a voluminous empirical literature in economics and sociology which is surveyed in Ioannides/Loury (2004). While we are not aware of a theoretical model that relates job matching quality directly to network size, recent theoretical contributions by Calvo-Armegnol/Jackson (2004, 2007) suggest that the accessibility of information on job opportunities increases with the size of career networks. Despite the lack of theoretical models, empirical studies support the idea that larger career networks transmit labor market information more efficiently and thereby increase matching efficiency in the labor market. Investigating the impact and structure of informal networks of Mexican immigrants, Munshi (2003) shows that workers in exogenously larger networks earn significantly higher wages, indicating higher productivity through more efficient job matches. Similarly, Datcher (1983) and Simon/Warner (1992) both show that in the face of difficult-to-observe job features, acquiring information about job characteristics through informal contacts significantly reduces the probability of a worker to quit a job later on.

Secondly, for human capital externalities to arise through improved matching opportunities it has to be the case that the size and with it the information content of career networks depend on aggregate human capital. Framed differently, our analysis rests on the idea that information on career options diffuses more rapidly and more effectively with higher regional levels of education. Theoretical models of the intensity of knowledge diffusion as a function of aggregate education have predominantly been developed in the economic literature on the transmission of

knowledge (Jovanovic/Nyarko 1995).⁵ Evidence on the matter has, in turn, predominantly come from sociological studies. These studies, which we briefly touched upon above, provide evidence that the number of social contacts increase with individual education. Since, logically, the amount of information an individual has access to through second or third order ties increases with the level of education of other members in the network, the size and the range of career networks can reasonably be assumed to increase with aggregate average education.

Thirdly, for regional wage differentials to be caused by varying levels of matching efficiency, career networks have to exhibit a strong local dimension. The theoretical insight that information diffuses most efficiently in networks exhibiting small world properties (Watts/Strogatz 1998, Cowan/Jonard 2004) is confirmed by a number of studies in economics and sociology. To date, Bayer/Ross/Topa (2008) provide the most sophisticated study on the geographical scope of career networks. Controlling for reverse causality and sorting effects, the authors provide robust evidence that individual career perspectives and wages are shaped through social interactions between workers within the same block of residence. Their study is complemented by a broad literature showing that face-to-face communication and peer effects within local environments enhance the diffusion of knowledge on job perspectives (Cutler/Glaeser 1997), entrepreneurial opportunities (Acs/Armington 2004), and innovation (Jaffe/Trajtenberg/Henderson 1993).⁶ The local nature of career networks is confirmed by numerous case studies. For instance, Combes/Linnemer/Visser (2008) show that personal networks, which are of prime importance for candidates to be successful in the centralized hiring procedure of economics professors in France, are of a strong local nature, i.e. are usually located within economics departments.

II.2. Identifying Matching Externalities: Two Approaches

Our identification strategy rests on two econometric approaches which correspond to the two hypotheses developed above. First, we analyze whether wage gains incurred by job changers increase with local aggregate education. Second, we examine whether workers in skilled regions display a higher propensity to change jobs earlier in life, while exhibiting a lower overall number of job changes when exiting the labor market. We take positive evidence on both hypotheses as indication for the existence of matching externalities arising from aggregate levels of human capital.

⁵ Word-of-mouth models, e.g. Ellison/Fudenberg (1995), are a class of social learning models which also provide valuable insight into processes of knowledge diffusion (see Sobel 2000 for a survey). The problem with these models with respect to our case is that they do not include individual or aggregate education as a parameter determining the speed or the structure of information flows.

⁶ See Brock and Durlauf (2001) for a comprehensive survey of the literature on social interaction.

Both hypotheses have their roots in the literature on agglomeration externalities, which posits that higher urban wages arise from improved matching opportunities in cities, made possible by a large number of workers and firms (Helsley/Strange 1990). Showing that wage gains of job changers are substantially larger in cities than in the countryside, Glaeser/Maré (2001) are the first to present empirical evidence for improved matching opportunities in cities as an explanation for higher urban wages. While their results are confirmed by Wheeler (2006), Yankow (2006) attributes the bulk of wage adjustments after job moves to wage growth effects, and thus to improved opportunities in cities to acquire productivity enhancing knowledge.

Analyzing regional differences in the patterns of job change, Bleakley/Lin (2007) find regional economic density to have a negative impact on the frequency of intra-regional job change for all but young workers. They interpret this finding as evidence that young workers in cities change jobs more often up to a point when they have found an optimal match within which they stay thereafter. Similar results with respect to the incidence of industry change are obtained by Freedman (2008), who shows that the probability of intra-industry change as compared to inter-industry job change is higher in agglomerated areas. Wheeler (2008) confirms these findings, but adds that the impact of agglomeration on job changes decreases with the number of prior job change and eventually becomes negative after the fourth move.

While both types of studies provide evidence for the occurrence of more efficient job matches in cities, one may contest that improved opportunities for labor market matching are caused by urban density alone. In fact, the close correlation between agglomeration and aggregate education leaves room for human capital externalities as an explanation for a higher quality of job matches in cities. In fact, since workers and firms usually lack information about the respective other (Jovanovic 1979), the availability of knowledge about potentially efficient matches is likely to be at least as important for matching efficiency as the sheer availability of jobs and workers. In this respect, career networks are of vital importance for efficient job matches to occur since they not only transmit information about jobs and workers available, but also reduce information asymmetries on unobservable characteristics of both parties.

With this consideration in mind we analyze whether aggregate human capital levels improve matching efficiency in regional labor markets. Doing so, we rely on the identification approaches suggested in the literature on agglomeration externalities.

Addressing the first hypothesis, we examine whether wage increases incurred on the incidence of job change depend on the regional level of education. We therefore

estimate Mincerian wage equations augmented by indicators for job change and regional human capital endowments, as well as interactions thereof.

$$w_{i,r,t} = \sum_{k=1}^K X_{k,i,t} \beta_k + \sum_{m=1}^M Z_{m,r,t} \gamma_m + \delta_1 M_{i,t} + \delta_2 HC_{r,t} + \delta_3 M_{i,t} \times HC_{r,t} + \phi_r + \phi_t + \varepsilon_{i,r,t} \quad (1)$$

More specifically, we estimate wage w of individual i at time t in region r as a function of k individual characteristics X_k , a number of m regional characteristics Z_m , the incidence of a job move M at time t , the share of highly qualified workers $HC_{r,t}$ in region r at time t , as well as the interaction between the latter two. Additionally, we control for region and time fixed effects. Our prime parameter of interest is δ_3 , which measures the extent to which wage gains incurred by job changers depend on the regional share of highly qualified workers. We interpret a positive parameter δ_3 as indication that regional aggregate education increases the quality of job matches.

Our second hypothesis states that with the existence of matching externalities from education the probability of a job change should be positively influenced by regional human capital endowments. This relationship should weaken with an increasing number of prior job changes. Investigating this issue we estimate equation (2),

$$\Delta J_{i,r,t} = \sum_{k=1}^K X_{k,i,t} \theta_k + \sum_{m=1}^M Z_{m,r,t} \vartheta_m + \tau HC_{r,t} + \phi_r + \phi_t + \varepsilon_{i,r,t} \quad (2)$$

which expresses the incidence of job change $\Delta J_{i,r,t}$ of individual i in region r at time t as a function of k individual and m regional characteristics X_k and Z_m , as well as of the share of highly qualified workers $HC_{r,t}$ in region r at time t . In addition, we control for region and time fixed effects. Our main parameter of interest is τ , which indicates whether regional human capital endowments influence the probability of intra-regional job changes. We first estimate equation (2) for all moves in order to see whether human capital rich regions display a systematically different incidence of job change. We then estimate it separately by the number of prior moves to examine whether the importance of aggregate education decreases in the course of a worker's career. Finally, we investigate whether workers in skilled regions have changed jobs less often when exiting the labor market than workers in unskilled regions.

Throughout our analysis we employ the regional share of highly qualified workers as our preferred measure of regional human capital. This is due to the following two considerations. First, we follow Krueger/Lindahl (1999) in their argument that productivity effects from aggregate human capital are more likely to be rooted in the regional share of highly qualified workers, rather than in the overall average level of

education. Second, for reasons outlined below we restrict our sample to highly qualified workers. Since Kremer (1997) shows that individuals sort into networks which are homogenous with respect to social status, education, and abilities, we expect the presence of other highly qualified workers to be more relevant for career opportunities of highly qualified workers than average levels of education in general.

We exclusively focus on highly qualified workers throughout the analysis, i.e. we estimate the importance of matching externalities arising from regional human capital endowments for highly qualified workers only. Since Ciccone/Peri (2006) it is well known that imperfect substitutability between highly qualified and non-highly qualified workers constitutes a serious threat to the proper identification of human capital externalities. Due to supply and demand effects, an increase in the regional share of highly qualified workers depresses wages of highly qualified workers while increasing those of non-highly qualified workers. With an increasing supply of highly qualified workers we are thus prone to overestimate human capital externalities when not differentiating their effects by qualification. Since the primary objective in this paper is to provide first evidence on whether matching externalities exist as a microeconomic source of human capital externalities, we have decided to focus on highly qualified workers alone, well aware that doing so we are likely to underestimate the size of matching externalities from aggregate education.

We define labor market regions along the lines of the 75 '*Raumordnungsregionen*' defined by the Federal Office for Building and Regional Planning, which are equal to NUTSII regions (BfLR 1996). While these regions are not explicitly defined so as to reflect workers' commuting behavior they do, by principle of construction, always cover a core city and its surrounding periphery (see Kosfeld/Eckey/Türck 2006).

We restrict our analysis to workers who move jobs without moving regions. Focusing on intra-region job movers allows us to identify matching effects from regional human capital more clearly by avoiding bias from several confounding factors. The biggest threat to a proper identification of human capital externalities stems from the fact that regional human capital exhibits amenity and productivity effects alike (Roback 1982). Thus, while regional human capital increases workers' productivity, it also constitutes an amenity inasmuch as workers might be willing to accept wage reductions in exchange for living and working in a more educated environment. Reducing our sample to workers changing jobs within regions implies that wage reducing amenity effects do not affect wage growth on the occasion of job change since pre-move wages are already amenity adjusted.

Secondly, workers moving regions tend to be highly self-selected with respect to unobservable but productivity relevant characteristics like motivation or ambition. Not controlling for these characteristics would lead to an overestimation of effects from human capital externalities. Routinely, this problem is addressed by including worker fixed effects. While we intended to do so, the use of worker fixed effects was made impossible by the small number of job moves in our data. Due to the resulting high collinearity between the fixed effects and the move dummy, our estimators on move effects and on the interactions with aggregate human capital, which are central to our analysis, did not converge. In the absence of workers fixed effects, reducing our sample to workers changing jobs within regions can be regarded as a second-best option to reduce unobserved heterogeneity between workers.⁷

Restricting the sample to within-region movers allows us to explicitly investigate the importance of regional aggregate education for the efficiency of job matches within regional labor markets. However, since career networks are likely to be of different importance for intra-regional and inter-regional job changers, our results are only to a limited extent transferable to workers changing regions. In order to shed light on the spatial scale of career networks we have estimated all our regressions for the full sample in order to see whether matching effects arise either in the same manner or to a different extent for those workers changing jobs between regions.

II.3. Human Capital Externalities and Matching: Data and Descriptives

Our empirical investigation is based on the IABS data set provided by the Institute for Labor and Employment Research in Nuremberg. The IABS is a two percent sample of all workers holding a job subject to social security contribution and contains longitudinal information on worker's employment histories, as well as on further individual characteristics (see Drews 2007 for a comprehensive description of the data). From this spell data we construct a panel data set encompassing all observations made on the 30th of June each year. This annualized panel data set contains more than 18 million observations for Western Germany between 1975 and 2004. The definition of worker status along the lines of social security contributions excludes self-employed workers as well as public servants.

One of the merits of the data set lies in its panel structure, which allows for tracking workers over time. Another merit is that the data are very reliable since they provide

⁷ A minor problem we eliminate when restricting our sample to workers changing jobs within regions is that when changing regions workers are sometimes compensated for moving efforts by their future employer. These one-time payments are inseparably incorporated in our data on wages and might introduce upward bias into our estimations on the importance of matching effects.

the source for calculating social benefits entitlements, and employers are therefore obliged to submit them to the best of their knowledge. The flipside of data being generated from the employment register is that wages are top coded at the threshold of maximum social security payments.⁵ We therefore have imputed wages above this threshold through predictions from a full set of individual characteristics (see Gartner 2005). Throughout the paper wages are defined as gross daily wages, which we have inflation adjusted to the 2004 Euro level. The education variable is a six-stage indicator containing information on a worker's highest degree of formal education. We have corrected for inconsistent coding of the education variable using an improved variable provided by Fitzenberger/Osikominu/Völter (2006) and Drews (2006). Part-time employees, apprentices and trainees are excluded from the data, which leaves 12 million observations on about one million full time employees in Western Germany between 1975 and 2004. For reasons outlined above we further restrict our data to contain only highly qualified workers, defined as workers holding a degree from a university or a technical college. This restriction reduces the number of observations to 873,109. In order to investigate the importance of matching externalities from aggregate human capital we construct two subsamples.

The first subsample contains a balanced panel of workers, encompassing all highly qualified employees with a full set of observations between 1999 and 2004, i.e. workers with a total of six observations in this period. As argued above, we require these workers to stay within one region, i.e. to neither move employers nor houses between regions. We therefore exclude all workers moving jobs or regions, except those changing jobs within regions in 2000. This leaves us with 110,454 observations on 18,409 workers, out of which 1,143, i.e. 6.21 percent, move firms in 2000 without moving regions. We define a dummy variable which equals 1 (0) if a worker belongs to the group of movers (stayers). Earmarking the group of movers over the whole period of investigation, rather than just for the year 2000, we control for systematic and persistent unobservable differences between movers and stayers. Focusing on job moves occurring in 2000 eliminates bias from changing macroeconomic environments, or systematic changes of motives for job moves over time, e.g. due to business cycles.

While providing insight into the average size of matching effects from aggregate human capital, the drawback of using a balanced panel containing just one job move is that it does not allow for examining whether such matching effects change with the number of prior job moves. With our theoretical considerations in mind, we expect the effect from aggregate human capital on wage gains of job movers, as well as on

⁵ The ten percent of workers earning wages above this threshold, which increases annually approximately in line with overall wage growth, are free to choose to either pay the maximum amount of social security payments, or to leave the public system and insure privately.

the propensity to change jobs, to decrease with the number of prior moves since workers in skilled regions are likely to have found an efficient job match earlier in life.

In order to address our second hypothesis and to corroborate our results obtained from the first sample we construct a second sample, which allows us to track workers from their career start over their employment life cycle. We construct this sample so as to contain only workers who show up for the first time in the data after 1975 (in order to avoid left-censoring), are below the age of thirty when observed for the first time, and who have a full set of observations until they either leave the labor market or until the sample ends in 2004.⁸ We again make sure that these persons stay within one region throughout their working life. This leaves us with a sample of 155,680 observations on 23,187 workers, i.e. we observe workers on average for a period of 6.7 consecutive years. Since workers can change jobs several times, we observe 10,522 job changes made by 6,814 persons. Thus, workers change jobs on average .83 times during the period of observation. Conditional on changing jobs at all, the average number of job changes is 1.74. Since the number of observations naturally decreases for larger numbers of job moves, we merge all moves above the third into one category, which then contains 450 observations on a worker's fourth move or beyond.

Maps I and II provide evidence of the close correlation between the regional shares of highly qualified workers and average regional wages earned by highly qualified workers across the 75 regions in Western Germany. High average wages and human capital intensities follow the well-known 'hot banana pattern', i.e. they follow an imaginary line starting in the North-West in the Rhineland, crossing the Rhine-Main area and the automobile cluster around Stuttgart, and continuing down to the South-East, i.e. to Bavaria. With respect to the importance of human capital externalities as a determinant of wages across the regions in Western Germany, employing the regional number of students and the number of schools as instrumental variables for the share of highly qualified workers in a region, Heuermann (2008) shows that while sorting effects of workers of different education and ability play an important role for higher wages in human capital intensive regions, external effects from human capital raise wages of highly qualified workers by 1.8 percent with each additional percent in the share of highly qualified workers. Thus, a one standard deviation in the regional share of highly qualified workers is associated with an increase in wages of about eight percent for highly qualified workers. In the following analysis we investigate to which extent wage effects from human capital externalities are attributable to improved matching opportunities arising from a higher density of human capital.

⁸ Quits from the sample can occur if workers change into the public service, become self-employed, become unemployed for more than a year, or leave the labor force altogether.

III. Matching as a Microeconomic Source of Human Capital Externalities

III.1. Between-Job Wage Adjustment: Evidence from a Balanced Panel

We start by examining wage developments within our balanced sample of workers. Graph I contains the evolution of average wages for the group of movers. With the exception of 2004, average wages increase over the whole period of observation at an average annual rate of 1.5 percent. Of particular interest is the wage jump occurring at the time of job change, i.e. between 1999 and 2000, where average wages rise by about four percent from below 118 to above 122 Euros. In what follows we examine the extent to which this wage growth is driven by gains from matching externalities.

Table I contains the results from estimating equation (1). All coefficients on individual characteristics are in line with the broad empirical literature, i.e. wages grow at a decreasing marginal rate with age, tenure, and experience. Furthermore, university graduates receive a wage premium of about eight percent compared to graduates from technical colleges, while women's wages are 37 percent below those of their male colleagues. These coefficients are constant across all wage regression in both samples and are not commented on further.

All columns consistently show that workers who move jobs in 2000 incur substantial wage gains from human capital externalities. While the overall effect of the regional share of human capital on wages of all workers (*'Regional Share HQ'*) is insignificant throughout all regressions, the significantly positive coefficient on the interaction term in Column I indicates that with a one percent increase in the regional share of human capital, wages of moving workers rise by .35 percent. Thus, an increase in the share of highly qualified workers by one standard deviation, i.e. by about 5.5 percent, is associated with wage gains of about two percent incurred by the group of movers.

In columns II to V in Table I we have differentiated the impact of regional human capital on wages of moving workers by year in order to see whether wage gains occur in the year of moving (*'Move Dummy*Regional Share HQ, 2000'*), which in line with our first hypothesis we would take as evidence that human capital externalities unfold through improved matching opportunities in skilled regions. The crucial insight from all four regressions is that on the incidence of moving jobs, i.e. in the year 2000, workers experience wage gains of between .27 and .58 percent with each additional percent of regional human capital. Our most comprehensive specification in column V confirms that matching externalities arising from aggregate human capital

increase wages at the time of moving by about .6 percent with every additional percent in the regional share of highly qualified workers. Thus, a one standard deviation of the share of highly qualified workers raises wages of job movers by about 3.2 percent. Insignificant coefficients on human capital externalities in all other years emphasize that benefits from regional human capital accrue to workers only in the event of a job change, i.e. through matching effects. Graph II summarizes the coefficients and confidence intervals obtained in this regression.

Two further insights emerge from columns III to V. We first differentiate the impact of regional human capital on all workers (*'Regional Share HQ'*) by year. Coefficients, which are not shown here, are insignificant for each year. In addition, our results on the impact of aggregate human capital on the wages of job movers remain unchanged. Both results confirm that human capital externalities unfold wage effects predominantly through more productive job matches of workers changing jobs. Second, we split up the move dummy (*'Move Dummy'*) by year in order to control for changes in systematic differences between movers and stayers. Doing so, we find that human capital effects after job moves lose significance, while the size of matching externalities doubles. These results confirm the findings by Freedman (2008) that workers are self-selected inasmuch as they accept lower wages when changing jobs but incur larger wage gains after job moves.

Two explanations come to mind for the significantly negative move dummy. Freedman (2008) argues that workers are willing to accept wage losses when changing jobs since they expect to benefit from steeper wage growth through improved career opportunities thereafter. Alternatively, Lehmer/Möller (2008) show that workers are self-selected with respect to pre-move wages, i.e. low-paid workers are more likely to change jobs. We have split up the move dummy by year in column IV so as to shed light on the issue. Results, which are not shown here, indicate that both arguments apply since wages of movers are significantly lower in the first two years of observation and increase faster, though not significantly, in the four years thereafter.

Our result that external human capital effects for workers other than job movers are insignificant stands in contrast to prior findings in the empirical literature. Such insignificance is likely to be driven by the short time horizon covered by our sample, rather than by the absence of genuine human capital externalities for job stayers. In fact, effects from aggregate human capital can arise only from intra-regional shifts in aggregate education, since level effects are captured altogether by our region fixed effects. As the sample covers a period of six years only, intra-regional variances in the share of highly qualified workers are probably too small to yield significant effects.

III.2. Between-Job Wage Adjustment: Evidence from an Unbalanced Panel

In order to corroborate these results and to examine whether matching externalities from aggregate human capital decline with the number of prior job moves we employ our second, unbalanced panel of workers. Specifically, rather than comparing the development of wages of a group of movers to that of non-movers, we now compare wage increases on the incident of a job move to wage developments of workers staying in their job. Technically, our move dummy therefore does not identify a worker as a mover any more, but indicates the incidence of a job move.

Columns I to III in Table II confirm our results obtained from the balanced sample of workers. Consistently, we find regional human capital externalities to raise wages at the time of a job change by between 2. and .3 percent with each additional percent in the regional share of human capital. Thus, increasing the share of highly qualified workers by one standard deviation is associated with between-job wage gains by about 1.7 percent. It is worth noting that in line with results from the first sample, without human capital externalities movers would incur wage losses of about .02 to .05 percent in the year after moving, again indicating the self-selection of movers.

In column II we run the same regression for the full sample of workers. Interestingly, if we include workers changing jobs across regions, matching effects from aggregate human capital fully disappear. As discussed above, this result is probably rooted in three mechanisms. First, since aggregate education is likely to unfold amenity effects, workers changing regions might be willing to accept lower wages in order to be close to higher aggregate levels of human capital. Such wage depressing amenity effects might eat up productivity effects from human capital and thereby render the coefficient insignificant. Second, workers changing regions are likely to be self-selected with respect to motivation and ambition. These effects are reflected in the move dummy, which is now significantly positive. If more motivated workers move to regions with larger human capital endowments, our specification does not allow for disentangling effects from human capital externalities from those arising from higher motivation. Thus, a potentially close correlation between the decision to move and regional human capital endowments might drive the highly significant move dummy, while yielding an insignificant interaction term. Finally, these results might be indicative for the localized nature of career networks. As argued above, such networks work best if workers change jobs on a regional scale. While certainly not definite on the issue, the fact that regional human capital does not lead to productivity effects for workers changing regions indirectly supports the notion that career networks work best if workers change jobs within regions.

In column III we juxtapose matching externalities arising from aggregate human capital to those arising from urban density. In line with the notion that information on potential job matches and their quality is more important for efficient labor market matches than the mere availability of jobs and workers, we find matching effects to be rooted in the density of human capital, rather than in the extent of agglomeration. In fact, while the size of the matching effect from aggregate human capital remains largely unchanged, the interaction between the move dummy and urban density is insignificant.

Results obtained from the unbalanced sample provide insight into the relative importance of matching externalities as a microeconomic source of human capital externalities. As mentioned, human capital externalities raise wages of all workers by about .5 percent with each additional percent of highly qualified workers, independent of whether workers move jobs or not. However, such productivity enhancing effects are prone to be underestimated since with the existence of amenity effects from human capital workers are willing to incur wage losses for being close to other skilled workers (Roback 1982). According to Shapiro (2006), productivity effects account for about two thirds of the social returns to human capital and amenity effects for the remaining third. Thus, productivity effects from aggregate human capital are likely to range somewhere around .8 percent for all workers. Job movers incur an additional .3 percent at the time of changing firms. Since workers in our sample change jobs only within regions, amenity effects are already included in their pre-move wages and continue to be so in post-move wages. Wage gains on the incidence of job moves are therefore not influenced by amenity effects and simply reflect increases in productivity. Given this reasoning, the productivity of movers rises by 1.1 percent with each additional percent of highly qualified workers in the workforce. With .3 percent points of this effect arising at the time of moving, matching effects from aggregate human capital account for about thirty percent of overall productivity enhancing returns to human capital.

The finding that wage effects from aggregate education accrue to a substantial extent to moving workers is in line with a dynamic interpretation of localized economies of scale gaining prominence. In fact, it is increasingly acknowledged that benefits from economic density do not automatically accrue to all workers alike, but are mainly incurred by workers who change jobs in urban and thereby reap gains from matching opportunities. In this vein, Yankow (2006: 160) argues that “coordination efficiencies in dense urban settings have a prominent role to play in any comprehensive explanation of the urban wage premium”. Analogously, human capital externalities arise to a large extent through improved labor market coordination in skilled regions.

We finally differentiate the occurrence of matching effects by the number of prior job moves. Results from this exercise, which are documented in column IV, suggest that benefits from improved matching opportunities increase from the first to the second move, while becoming insignificant thereafter. The finding of an inverted U-shape of benefits from matching externalities to arise over the life cycle supports the idea that increasing the share of highly qualified workers enables workers to learn about job and career opportunities early in their working life and to capitalize on this knowledge through improved job matching during the first two job changes. However, two caveats apply. On the one hand, the number of workers changing jobs more than twice becomes very small with 841 workers being observed changing jobs for the third time, and 450 at the point of a fourth job change, compared to 6,814 first, and 2,417 second job changes. The decreasing incidence of job changes of higher ranks might inflate standard errors, which in turn decreases the reliability of estimates with an increasing number of job changes. Secondly, motives of job change might become more diverse over time. Thus, one might argue that career perspectives can be expected to play a dominant role as a motive for job change first and foremost in earlier stages of a workers life. Consequently, career networks might lose importance not because they transmit less usable information, but because workers preferences for making a career change over time. In this respect it is unfortunate that our dataset does not allow us to control for job changes occurring voluntarily or involuntarily, a distinction which can be expected to matter for wage developments over time. Thus, while our results need validation from other data sets which allow for the inclusion of motives of job change, our findings from the wage regressions strongly support the notion that productivity enhancing human capital externalities arise through improved matching opportunities in skilled regions.

III.3. The Probability of Job Moves

Table III contains results from Probit regressions on individual and aggregate determinants of job changes. We use both samples in order to corroborate our results. We restrict the first sample to the year 2000, since by means of construction job changes only occur in that year. Thus, we investigate the determinants of job moves for a cross-section of 18,409 workers, out of which 1,143 change jobs. Restricting the dataset like this impedes the use of time or region fixed effects. The second sample encompasses all 155,272 observations. The dependent variable throughout all regressions is the incident of job change, irrespective of the number of prior moves.

Due to differences in the samples (with the first sample covering all workers in 2000 and the second sample consisting of observations on young workers between 1976 and 2004) the coefficients on individual variables vary slightly. However, all coefficients

show the same plausible signs in all regressions. Age and experience follow an inverted U-shape pattern, indicating that the probability of job change first increases with age and labor market experience, and declines thereafter. Thus, in line with Battu/McMaster/White (2002), we find that job change is primarily an issue of earlier stages of a worker's career. In contrast, the probability of job change decreases with tenure. This is consistent with theoretical arguments by Jovanovic (1979) and empirical findings by Mincer/Jovanovic (1981) and Farber (1999), who show that the disclosure of information on the quality of a job match is initially high and declines over time, leading to a gradually decreasing probability of job change. Finally, women change jobs more often, while we find basically no difference in the job change behavior between university graduates and graduates from technical colleges.

The regional share of highly qualified workers exerts a significantly positive influence on the probability of job change, indicating that workers change jobs more often in skilled regions. Results are very similar across the two samples. In fact, an increase of the share of highly qualified workers by one standard deviation increases the annual probability of job change by between .1 and .3 percent in both samples. Graph III contains a simulation of the probability of job change as a function of regional human capital endowments based on the linear specification contained in column IV. The probability of job change increases monotonically with the regional share of highly qualified workers at a growing marginal rate. Thus, raising the regional share of highly qualified workers by one standard deviation to its mean in 2004, i.e. from three to eight percent, is associated with an increase in job change probability of about .1 percent, while a rise by one standard deviation from eight to thirteen percent increases the probability by more than .3 percent. Workers in regions with a share of regional human capital exceeding seventeen percent are about one percent more likely to change jobs in a given year due to human capital externalities compared to workers in cities with human capital shares below five percent.

The finding that job change probabilities increase more than proportionally with human capital intensity suggests that career networks are predominantly an issue of highly qualified cities, whereas for intermediate levels of human capital intensity effects from improved matching opportunities are not overwhelmingly large. Typically, regions with high shares of highly qualified workers are characterized by a strong clustering of industries. These regions encompass Frankfurt (banking), Ludwigshafen (chemical industry), Stuttgart (automobile industry), and Munich (computer engineering). It is therefore very likely that matching efficiencies do not only depend on the level of regional human capital, but also on the extent to which regional industrial compositions allow workers to capitalize on their industry-specific

human capital. Accordingly, Fallick/Fleischman/Rebitzer (2006) provide evidence that high job-hopping rates in Silicon Valley identified by Saxenian (1994) are entirely driven by job movers within the computer industry, while job changing rates within other industries are not significantly higher than elsewhere. We provide evidence on the importance of within-industry moves for the occurrence of matching externalities below. Before doing so, two further comments are in order, one relating to our results on agglomeration effects, and one on the changing importance of human capital networks for job matching in the course of a worker's career.

Turning to agglomeration, in contrast to Finney/Kohlhase (2007), we find only limited evidence for a positive impact of regional agglomeration on the probability of job change. In contrast, while aggregate education is a robust predictor of job change across both samples, urban density unfolds significant effects only in our first sample. Thus, our findings suggest that the local density of human capital is at least as important as regional labor market size for the propensity to change jobs. We do admit, however, that the impact of agglomeration on job change probabilities might be more complex than we have modeled it here. The results by Bleakley/Lin (2007) point to pronounced nonlinearities in the importance of agglomeration for job changes. Acknowledging that the size of labor market might matter in different and potentially more complex ways than investigated here we leave this issue for further investigation within the literature on agglomeration externalities.

With respect to the changing importance of human capital networks in the course of workers' careers, in Table IV we estimate the probability of a move conditional on the number of prior moves. Technically, our move dummy in each regression equals one if a move of a specific rank is observed, e.g. in column I (II) the dependent variable equals one if a worker makes his first (second) job move. In order to avoid logical inconsistencies, we exclude moves of higher ranks from each regression. Theoretically, the number of observations should therefore rise with the number of prior moves, which is why column I contains more observations than column II. This number decrease in column III and IV since in some years in some regions no job change is observed, which necessitates that for reasons of identification all observations within these entities are dropped.

As our core result we find regional human capital to be statistically significant only for a worker's first move, indicating that human capital networks are relevant first and foremost in early stages of a worker's career. Analogously, Wheeler (2008) finds that agglomeration facilitates the search for an efficient job match early in life. While following Wheeler in his argument that external labor market structures are of prime

importance especially early in a worker's career, we do not find evidence for an important role of agglomeration in and by itself in our sample of highly qualified workers. Instead, highly qualified workers seem to profit from the density of human capital rather than from market size alone.

Finally, we employ Tobit regressions in order to shed light on the impact of regional human capital on the total number of job moves made by a worker during the period of observation. Doing so allows us to indirectly assess whether career networks in skilled regions enable workers to find an efficient job match earlier than their colleagues in regions shaped by lower human capital endowments. As our dependent variable we use the total number of job moves made by a worker, which is bounded between 0 and 4, and estimate it as a function of a full set of individual and aggregate characteristics. The results are contained in column V in Table IV. Using a linear specification we find regional human capital to significantly reduce the overall number of job moves. More specifically, workers in regions characterized by a regional share of highly qualified workers of one standard deviation below the mean have changed jobs on average .2 times more than their colleagues in regions with an average share. With respect to agglomeration, we find that increasing the size of a region by twenty-five thousand workers increases the average number of job changes by one. A word of caution is in order, though. For reasons outlined above our sample is constructed so as to track workers in their careers as long as they stay within one region. It could theoretically be that our results are driven by an increased probability of workers in human capital intensive regions to change regions more often and therefore to drop out of our sample earlier. Although we do not find evidence for different lengths of observations in our data, our results on the impact of regional human capital on the total number of job changes need further validation. We leave this as an avenue for further research, drawing the preliminary conclusion that while matching externalities in skilled regions raise the probability of changing jobs early, they reduce the overall number of job changes needed for workers to find an efficient labor market match.

IV. Human Capital Externalities and the Transfer of Industry-Specific Human Capital

Results obtained so far are supportive of the idea that human capital networks improve matching efficiency in the labor market by providing ex ante information on the quality of a job match between workers and employers. Among other things, the quality of such a match depends on the extent to which a worker can transfer his

knowledge and experience obtained in past positions into a new environment and thereby continues to use it productively. With respect to industry-specific knowledge, successful transfers are most likely if workers change between firms within one industry. Career networks might therefore play an important role in enabling workers to continue their career within one industry and allow them to capitalize on their experience obtained in past jobs. Accordingly, existing studies in the literature on agglomeration have confirmed that benefits from agglomeration are partly rooted in the fact that cities are home to larger industries, which in turn facilitates the transfer of industry-specific knowledge between jobs (Freedman 2008, Wheeler 2008). We follow this line of enquiry by examining whether career networks enable workers to reap benefits by facilitating job changes within industries. We therefore first investigate the existence of industry-specific human capital by analyzing whether benefits are different for job matches between industries and within industries. We then examine whether workers are more likely to stay within an industry in human capital intensive regions.

Column V in Table II contains our results from an estimation of wage gains from matching externalities differentiated by the type of job move. The coefficients on the interaction terms emphasize the importance of industry-specific human capital by indicating that aggregate human capital yields matching benefits only to workers changing jobs within an industry. More specifically, when disaggregating industry-wage regressions by number of move we find the same pattern of benefits as in our general analysis, i.e. matching externalities arise predominantly with the first two intra-industry job changes, while becoming insignificant thereafter (results not shown here). With respect to the importance of career networks, this finding suggests that such networks predominantly carry information about job opportunities within an industry and thereby increase the chances of workers to capitalize on their industry-specific human capital. In contrast, when changing jobs to other industries, between-job wage growth does not depend on regional human capital. However, differences in the motives of job change may induce a hidden source of heterogeneity between intra-industry and between-industry changers. While for reasons outlined above we cannot directly test for such heterogeneity, we are confident that the bulk of self-selection effects are captured by the move dummy rather than by the interaction term. This interpretation hinges on the assumption that unobserved heterogeneity between workers does not systematically change with the density of human capital.

If only workers who change jobs within their own industry profit from increased matching opportunities arising from the density of highly qualified workers, we should find that workers in human capital intensive areas predominantly change jobs within their own industry in order to reap the gains from such matching externalities.

We therefore reduce our two samples to their respective subsample of job movers and employ Probit regressions in order to estimate the probability of industry change as a function of regional human capital, conditional on a worker changing jobs.

Table V contains the results of this estimation. Column I shows that for the first sample of job movers the probability of industry change declines with the regional share of highly qualified workers. This result is, however, not robust to the inclusion of the agglomeration variables as further controls. Thus, while still negative, the coefficient on regional human capital density becomes insignificant. Since this regression is based on a cross section of observations only, a proper identification is impeded by strong multicollinearities between human capital density and agglomeration due to the relatively small number of observations. A larger number of observations in the second dataset solves this problem.

Column II in Table V contains our results from using the second sample of job movers. The regional share of highly qualified workers again unfolds a negative impact on the propensity of job changers to change industries. This result is not only robust to the inclusion of increasing returns from agglomeration, but even increases in size. Based on the results in column III, Graph IV contains a simulation of the probability of an industry change associated with changes in the regional density of human capital. It shows that the negative effect is, indeed, large. With a share of regional human capital below five percent, the overall probability of a worker changing industries when changing jobs ranges around sixty percent. In regions characterized by a share of highly qualified workers of above fifteen percent this probability reduces to well below forty percent. In general, increasing the regional share of human capital by one standard deviation decreases the probability of industry change by about ten percent.

In column IV we split up the propensity of changing industry by the number of prior job moves. This line of inquiry is inspired by Wheeler (2008), who finds that industry changes occur less frequently in later phases of a worker's life cycle. We find no such evidence. In fact, the negative impact of human capital networks on the probability of industry changes remains remarkably constant over time. This indicates that workers use information networks over their life cycle in order to stay within their industries. In contrast to Bleakley/Lin (2007), who show that workers of all educational backgrounds change occupation and industry less frequently in agglomerated areas, we find that highly qualified workers mainly benefit from the density of human capital, which allows them to change jobs within industries. One slight contradiction seems to emerge, however. While from the third move onwards

gains from changing jobs within industries do not capitalize in wages anymore, workers still continue to change jobs within industries in later stages of their careers. Possibly, the number of cases gets too small to allow for a proper identification of wage gains with a higher number of job changes. Alternatively, workers stay in their industries due to a preference for doing a job they are familiar with. Thus, while we cannot say exactly what happens after the second move, the general picture emerging from the data supports the idea that information networks embedded in the density of regional human capital enable workers to gather information on superior job matches which allow them to capitalize on their industry-specific human capital. Thus, it is through the opportunity of changing jobs within industries that regional human capital enables young workers to climb up the income ladder more quickly especially in early stages of their career.

V. Conclusion

This paper set out with the intent to take Gilles Duranton's advice serious and to try to shed light on the microeconomic foundations of human capital externalities. Inspired by a voluminous literature on the importance of social networks for career perspectives, we investigated whether productivity enhancing effects of regional human capital endowments come about through an improved quality of job matches in human capital rich regions. Employing two samples of highly qualified workers from Germany we examined the extent to which regional differences in between-job wage growth and in job moving behavior are attributable to differences in regional educational endowments as measured by the share of highly qualified workers. Our findings strongly support the notion that regional human capital externalities are rooted in improved job matching opportunities arising from a more efficient flow of information on career and job opportunities. Three core findings emerge.

First, we find an increase of the share of highly qualified workers by one standard deviation to be associated with wage gains of job movers between 1.5 to 3.2 percent. This finding supports the idea that highly qualified workers profit from having access to a dense network of other highly qualified workers, which we interpret as being indicative of a more widespread diffusion of labor market information within career networks leading to more efficient job matches.

Second, an increase in the share of highly qualified workers by one standard deviation raises the annual probability of a job change by up to .4 percent. Differentiating this impact by the number of prior job moves we find it to be especially pronounced in

early stages of a workers' career. Combined with the insight that workers change jobs less often in skilled regions, this result supports the notion that career networks allow highly qualified workers to change jobs early in their career up to a point where they find a job match of sufficient quality within which they stay thereafter.

Third, the occurrence of matching externalities from aggregate human capital is driven by the fact that career networks allow workers to change jobs within industries, allowing them to capitalize on their industry-specific human capital. This result is rooted in our finding that conditional on changing jobs, between-job wage gains accrue only to those workers who change jobs within industries. Consistent with this finding, workers in human capital intensive areas are more likely to change jobs within, rather than between industries.

While providing first evidence on the importance of improved job matching as a microeconomic foundation of human capital externalities, our study leaves a number of questions for further research. First, so far we only have provided evidence that highly qualified workers profit from dense networks consisting of their likes. In order for a coherent picture of human capital externalities to emerge, the analysis should be extended to examine the importance of different measures of aggregate human capital for groups of different educational backgrounds. In effect, this amounts to testing whether Krueger/Lindahl (1999) are right in assuming that the two types of aggregate human capital unfold dissimilar effects for different parts of the population. Up to now, uncertainty on the size and the underlying mechanisms through which different types of human capital externalities affect wages of different educational groups prevails. In fact, while Moretti (2004b) argues that human capital externalities are more pronounced for workers of lower skills groups in the US, Heuermann (2008) finds the reverse using data on Germany. For a deeper understanding of the mechanisms underlying such diverging results, future research on human capital externalities is encouraged to go beyond a mere quantification of external effects from human capital and to further the identification of the microeconomic sources of human capital externalities. In this respect we regard the taxonomy by Duranton/Puga (2004) of sharing, matching, and learning mechanisms, as well as the empirical study by Charlot/Duranton (2004) on the importance of workplace communication for human capital externalities, as ideal starting points for future investigations.

A deeper understanding of the detailed mechanisms through which human capital externalities arise for different subgroups is of prime importance for the design of labor market, regional, and educational policies. While with the existence of

externalities the need for public action is self-evident, the design and implementation of efficient policy measures is blurred by the lack of knowledge about, first, the relative importance of the microeconomic mechanisms through which human capital externalities arise and, secondly, about which type of aggregate education is most important for different educational groups so as to maximize their benefits from human capital externalities. In the words of Duranton (2006: 37), “after 10 years of work on human capital externalities in cities, there is a strong suspicion that ‘something is going on’, a weaker suspicion that such externalities might be quite large, and a hunch that direct interactions might not be everything”. Given the considerable cost of educational systems, more insights into how external effects from education come about and how social returns from aggregate human capital are distributed among different groups is clearly needed so as to design appropriate and well informed policy measures which are able to maximize society’s gains from education and to thereby enhance productivity and growth.

References

- Acs, Zoltan J. and Catherine Armington. 2004. The Impact of Geographic Differences in Human Capital on Service Firm Formation Rates. *Journal of Urban Economics* 56: 244-78.
- Audretsch, David B. and Maryann P. Feldman. 2004. Knowledge Spillovers and the Geography of Innovation; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Battu, Harminder, Robert McMaster and Michael White. 2002. Tenure and Employment Contracts – An Empirical Investigation. *Journal of Economic Studies* 29: 131-49.
- Bayer, Patrick, Stephen L. Ross and Giorgio Topa. 2008. Place of Work and Place of Residence: Informal Hiring Networks and Labor Market Outcomes. *Journal of Political Economy* 116: 1150-96.
- Bundesforschungsanstalt für Landeskunde und Raumordnung. 1996. Neuabgrenzung der Raumordnungsregionen. *Mitteilungen und Informationen der BfLR*: 4-5.
- Black, Duncan and Vernon Henderson. 1999. A Theory of Urban Growth. *The Journal of Political Economy* 107: 252-84.
- Bleakley, Hoyt and Jeffrey Lin. 2007. Thick-Market Effects and Churning in the Labor Market: Evidence from U.S. Cities. *Reserve Bank of Philadelphia Working Paper* 07-23.
- Boorman, Scott A. 1975. A Combinatorial Model for Transmission of Job Information through Contact Networks. *The Bell Journal of Economics* 6: 216-49.
- Brock, William A. and Steven N. Durlauf. 2001. Interactions-Based Models; in: Heckman, James J. and Edward Leamer (eds.) *Handbook of Econometrics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Calvo-Armegnol, Antoni and Matthem O. Jackson. 2004. The Effects of Social Networks on Employment and Inequality. *American Economic Review* 94: 426-54.
- Calvo-Armegnol, Antoni and Matthem O. Jackson. 2007. Networks in Labor Markets: Wage and Employment Dynamics and Inequality. *Journal of Economic Theory* 132: 27-46.
- Casper, Steven and Fiona Murray. 2005. Careers and Clusters: Analyzing the Career Network Dynamic of Biotechnology Clusters. *Journal of Engineering and Technology Management* 22: 51-74.
- Charlot, Sylvie and Gilles Duranton. 2004. Communication Externalities in Cities. *Journal of Urban Economics* 56: 581-613.
- Ciccone, Antonio and Giovanni Peri. 2006. Identifying Human-Capital Externalities: Theory with Applications. *Review of Economic Studies* 73: 381-412.
- Combes, Pierre-Philippe, Laurent Linnemer and Michael Visser. 2008. Publish or Peer-Rish? The Role of Skills and Networks in Hiring Economics Professors. *Labour Economics* 15: 423-41.
- Cowan, Robin and Nicolas Jonard. 2004. Network Structure and the Diffusion of Knowledge. *Journal of Economic Dynamics and Control* 28: 1557-75.
- Cutler, David M. and Edward L. Glaeser. 1997. Are Ghettos Good or Bad? *The Quarterly Journal of Economics* 112: 827-72.
- Datcher, Linda. The Impact of Informal Networks on Quit Behavior. *The Review of Economics and Statistics* 65: 491-5.

- Davies, Jim B. 2002. Empirical Evidence on Human Capital Externalities. *Working Paper* 2003-11, Department of Finance, Canada.
- Drews, Nils 2006. Qualitätsverbesserung der Bildungsvariable in der IAB-Beschäftigtenstichprobe 1975 – 2001. *FDZ Methodenreport* No. 5, Federal Employment Agency, Nuremberg.
- Drews, Nils. 2007. Variablen der schwach anonymisierten Version der IAB-Beschäftigtenstichprobe 1975 – 2004. *FDZ Datenreport* 3/2007, Federal Employment Agency, Nuremberg.
- Duranton, Gilles. 2006. Human Capital Externalities in Cities: Identification and Policy Issues; in: Arnott, Richard and Daniel McMillen (eds.) *A Companion to Urban Economics*. Oxford: Blackwell Publishing Ltd.
- Duranton, Gilles and Diego Puga. 2004. Micro-foundations of Urban Agglomeration Economies; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Eckey, Hans-Friedrich, Reinhold Kosfeld and Matthias Türck. 2006. Abgrenzung deutscher Arbeitsmarktregionen. *Raumforschung und Raumordnung* 64: 299-309.
- Ellison, Glenn and Drew Fudenberg. 1995. Word-of-Mouth Communication and Social Learning. *Quarterly Journal of Economics* 110: 93-125.
- Fallick, Bruce, Charles A. Fleischman and James B. Rebitzer. 2006. Job Hopping in Silicon Valley: The Micro-Foundations of a High Technology Cluster. *The Review of Economics and Statistics* 88: 372-81.
- Farber, Henry S. 1999. Mobility and Stability: The Dynamics of Job Change in Labor Markets; in: Ashenfelter, Orley and David Card (eds.) *Handbook of Labor Economics* Vol 3. Amsterdam: Elsevier-North Holland.
- Finney, Miles M. and Janet E. Kohlhase. 2007. The Effect of Urbanization on Labor Turnover. *Journal of Regional Science* 48: 311-28.
- Fischer, Claude S. 1982. *To Dwell Among Friends: Personal Networks in Town and City*. Chicago: University of Chicago Press.
- Fitzenberger, Bernd, Aderonke Osikominu and Robert Völter. 2006. Imputation Rules to Improve the Education Variable in the IAB Employment Subsample. *Discussion Paper* No. 5, Center for Doctoral Studies in Economics and Management, University of Mannheim.
- Freedman, Matthew L. 2008. Job Hopping, Earning Dynamics, and Industrial Agglomeration in the Software Publishing Industry. *Journal of Urban Economics* 64: 590-600.
- Gartner, Hermann. 2005. The Imputation of Wages above the Contribution Limit with the German IAB Employment Sample. *FDZ Methodenreport* No. 2, Federal Employment Agency, Nuremberg.
- Glaeser, Edward L. and David C. Maré. 2001. Cities and Skills. *Journal of Labor Economics* 19: 316-42.
- Glaeser, Edward L. and Jesse M. Shapiro. 2003. Urban Growth in the 1990s: Is City Living Back? *Journal of Regional Science* 43: 139-65.
- Granovetter, Mark. 1974. *Getting a Job – A Study of Contacts and Careers*. Cambridge, MA: Harvard University Press.
- Granovetter, Mark. 1983. The Strength of Weak Ties: A Network Theory Revisited. *Sociological Theory* 1: 201-33.

- Grossetti, Michael. 2007. Are French Networks Different? *Social Networks* 29: 391-404.
- Halfdanarson, Benedikt, Daniel F. Heuermann and Jens Südekum. 2008. Human Capital Externalities and the Urban Wage Premium – Two Literatures and their Interrelations. IZA Discussion Paper 3493.
- Helsley, Robert W. and William C. Strange. 1990. Matching and Agglomeration Economies in a System of Cities. *Regional Science and Urban Economics* 20: 189-212.
- Heuermann, Daniel F. 2008. Human Capital Externalities in Western Germany. *IAAEG Discussion Paper* 05/2008. University of Trier.
- Ioannides, Yannis M. and Linda Datcher Loury. 2004. Job Information Networks, Neighborhood Effects, and Inequality. *Journal of Economic Literature* 62: 1056-93.
- Jaffe, Adam B., Manuel Trajtenberg and Rebecca Henderson. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics* 108: 577-98.
- Jeger, Mike J., Marco Pautasso, Ottmar Holdenrieder and Mike W. Shaw. 2007. Modelling Disease Spread and Control in Networks: Implications for Plant Science. *New Phytologist* 174: 279-97.
- Jovanovic, Boyan. 1979. Job Matching and the Theory of Turnover. *Journal of Political Economy* 87: 972-90.
- Jovanovic, Boyan and Yaw Nyarko. 1995. The Transfer of Human Capital. *Journal of Economic Dynamics and Control* 19: 1033-64.
- Jovanovic, Boyan and Rafael Rob. 1989. The Growth and Diffusion of Knowledge. *Review of Economic Studies* 56: 569-82.
- Kremer, Michael. 1997. How Much Does Sorting Increase Inequality? *Quarterly Journal of Economics* 112: 115-39.
- Krueger, Alan B. and Mikael Lindahl. 1999. Education for Growth in Sweden and the World. *Swedish Economic Policy Review* 6: 289-339.
- Lehmer, Florian and Joachim Möller. 2008. Group Specific Effects of Interregional Mobility on Earnings – A Microdata Analysis for Germany. *Regional Studies* 42: 657-74.
- Lucas, Robert E. 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* 22: 3-42.
- Mincer, Jacob and Boyan Jovanovic. 1981. Labor Mobility and Wages; in: Rosen, Sherwin (ed.) *Studies in Labor Markets*. Chicago: University of Chicago Press.
- Moretti, Enrico. 2004a. Human Capital Externalities in Cities; in: Henderson, James V. and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Elsevier: San Diego, Oxford, London.
- Moretti, Enrico. 2004b. Estimation the social return to higher education: evidence from longitudinal and repeated cross-sectional data. *Journal of Econometrics* 121: 175-212.
- Munshi, Kaivan. 2003. Networks in the Modern Economy: Mexican Migrants in the U.S. Labor Market. *The Quarterly Journal of Economics* 118: 549-99.
- Ottaviano, Gianmarco and Jacques-Francois Thisse. 2004. Agglomeration and Economic Geography; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.

- Podolny, Joel M. and James N. Baron. 1997. Resources and Relationships: Social Networks and Mobility in the Workplace. *American Sociological Review* 62: 673-93.
- Rauch, James E. 1993. Productivity Gains from Geographic Concentration of Human Capital: Evidence from the Cities. *Journal of Urban Economics* 34: 380-400.
- Roback, Jennifer. 1982. Wages, Rents, and the Quality of Life. *Journal of Political Economy* 90: 1257-78.
- Rosenthal, Stuart S. and William C. Strange. 2008. The Attenuation of Human Capital Spillovers. *Journal of Urban Economics* 64: 373-89.
- Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Simon, Curtis J. and Clark Nardinelli. 2002. Human Capital and the Rise of American Cities 1900-1990. *Regional Science and Urban Economics* 32: 59-96.
- Simon, Curtis J. and John T. Warner. 1992. Matchmaker, Matchmaker: The Effects of Old Boy Networks on Job Match Quality, Earnings, and Tenure. *Journal of Labor Economics* 10: 306-30.
- Sobel, Joel. 2000. Economists' Models of Learning. *Journal of Economic Theory* 94: 241-61.
- Watts, Duncan J. and Steven H. Strogatz. 1998. Collective Dynamics of Small-World Networks. *Letters to Nature* 393: 440-442.
- Wheeler, Christopher H. 2006. Cities and the Growth of Wages among Young Workers: Evidence from the NLSY. *Journal of Urban Economics* 60:162-84.
- Wheeler, Christopher H. 2008. Local Market Scale and the Pattern of Job Change among Young Men. *Regional Science and Urban Economics* 38: 101-18.
- Yankow, Jeffrey J. 2006. Why Do Cities Pay More? An Empirical Examination of Some Competing Theories of the Urban Wage Premium. *Journal of Urban Economics* 60: 139-61.

Appendix

Table I – Do Workers Benefit from Regional Human Capital when Changing Jobs?

	Dependent Variable: Ln(Individual Daily Gross Wage)				
	(I)	(II)	(III)	(IV)	(V)
Age	.006 (.001)***	.006 (.001)***	.006 (.001)***	.006 (.001)***	.006 (.001)***
Age ²	-.0001 (.00001)***	-.0001 (.00001)***	-.0001 (.00001)***	-.0001 (.00001)***	-.0001 (.00001)***
Experience	.012 (.0009)***	.012 (.0009)***	.012 (.0009)***	.012 (.0009)***	.012 (.0009)***
Experience ²	-.00003 (.00003)	-.00002 (.00003)	-.00002 (.00003)	-.00002 (.00003)	-.00002 (.00003)
Tenure	.004 (.0007)***	.004 (.0007)***	.004 (.0007)***	.004 (.0007)***	.004 (.0007)***
Tenure ²	-.00007 (.00002)***	-.00008 (.00002)***	-.00008 (.00002)***	-.00008 (.00002)***	-.00008 (.00002)***
Sex	-.369 (.002)***	-.369 (.002)***	-.369 (.002)***	-.369 (.002)***	-.369 (.002)***
University Degree	.083 (.002)***	.083 (.002)***	.083 (.002)***	.083 (.002)***	.083 (.002)***
Regional No of Workers	-.003 (.004)	-.004 (.004)	-.003 (.005)	-.003 (.004)	-.002 (.005)
Regional Share HQ	-.346 (.360)	-.444 (.361)	Split up by Year, results not shown	-.372 (.363)	Split up by Year, results not shown
Move Dummy	-.056 (.015)***	-.047 (.015)***	-.047 (.015)***	Split up by Year, results not shown	Split up by Year, results not shown
Move Dummy*Regional Share HQ	.345 (.107)***	Split up by Year	Split up by Year	Split up by Year	Split up by Year
Move Dummy*Regional Share HQ, 1999	-	-.029 (.139)	-.038 (.140)	.381 (.279)	.341 (.285)
Move Dummy*Regional Share HQ, 2000	-	.268 (.136)**	.269 (.136)**	.560 (.268)**	.582 (.275)**
Move Dummy*Regional Share HQ, 2001	-	.329 (.131)***	.331 (.131)**	.067 (.258)	.066 (.264)
Move Dummy*Regional Share HQ, 2002	-	.397 (.126)***	.401 (.126)***	.207 (.249)	.232 (.255)
Move Dummy*Regional Share HQ, 2003	-	.385 (.123)***	.383 (.123)***	.351 (.250)	.346 (.255)
Move Dummy*Regional Share HQ, 2004	-	.320 (.123)***	.319 (.123)***	.150 (.254)	.144 (.259)
Year Dummies	Yes	Yes	Yes	Yes	Yes
Region Dummies	Yes	Yes	Yes	Yes	Yes
Sample	Sample I, All Workers Staying in a Region	Sample I, All Workers Staying in a Region	Sample I, All Workers Staying in a Region	Sample I, All Workers Staying in a Region	Sample I, All Workers Staying in a Region
Adj. R ²	.24	.24	.24	.24	.24
No. of Observations	110,454	110,454	110,454	110,454	110,454

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors for Regional Number of Workers are multiplied by 1,000; the education variable equals 0 for 'Degree from a Technical College' and 1 for 'Degree from a University'; the variable on a worker's sex equals 0 for 'Male' and 1 for 'Female'.

Table II – Do Workers Benefit from Regional Human Capital when Changing Jobs?

	Dependent Variable: Ln(Individual Daily Gross Wage)				
	(I)	(II)	(III)	(IV)	(V)
Regional Share HQ	.521 (.111)***	.433 (.083)***	.526 (.111)***	.516 (.111)***	.344 (.123)***
Regional No of Workers	-.003 (.001)**	-.003 (.001)**	-.003 (.001)**	-.003 (.001)**	-.002 (.001)
Move Dummy	-.019 (.009)**	.028 (.005)***	-.020 (.009)**	-	-
Move Dummy*Regional Share HQ	.272 (.078)***	.007 (.046)	.219 (.105)**	-	-
Move Dummy*Regional No of Workers	-	-	.0006 (.0007)	-	-
Move Dummy, 1 st Move	-	-	-	-.006 (.011)	-
Move Dummy, 2 nd Move	-	-	-	-.061 (.020)***	-
Move Dummy, 3 rd Move	-	-	-	-.045 (.035)	-
Move Dummy 4 th Move	-	-	-	-.154 (.049)***	-
1 st Move Dummy*Regional Share HQ	-	-	-	.287 (.096)***	-
2 nd Move Dummy*Regional Share HQ	-	-	-	.485 (.159)***	-
3 rd Move Dummy*Regional Share HQ	-	-	-	.218 (.276)	-
4 th Move Dummy*Regional Share HQ	-	-	-	.642 (.379)*	-
Move Dummy, Intra-Industry Move	-	-	-	-	-.053 (.014)***
Move Dummy, Inter-Industry Move	-	-	-	-	.009 (.013)
Intra-Industry-Move Dummy*Regional Share HQ	-	-	-	-	.520 (.125)***
Inter-Industry-Move Dummy*Regional Share HQ	-	-	-	-	.061 (.114)
Year Dummies	Yes	Yes	Yes	Yes	Yes
Region Dummies	Yes	Yes	Yes	Yes	Yes
Sample	Sample II, All Workers Staying in a Region	Sample II, All Workers	Sample II, All Workers Staying in a Region	Sample II, All Workers Staying in a Region	Sample II, All Workers Staying in a Region
Adj. R ²	.33	.32	.33	.33	.33
No. of Observations	155,680	268,383	155,680	155,680	155,680

Notes: Since coefficients on individual attributes are similar to those in Table I, they are not displayed here; standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors for Regional Number of Workers and interactions terms containing Regional Number of Workers are multiplied by 1,000.

Table III – Does Regional Human Capital Increase the Probability of Intra-Regional Job Moves?

	Dependent Variable: Incident of Job Change				
	(I)	(II)	(III)	(IV)	(V)
Age	.035 (.027)	.033 (.027)	.130 (.015)***	.129 (.015)***	.130 (.015)***
Age ²	-.0004 (.0003)	-.0004 (.0003)	-.0007 (.0002)***	-.0007 (.0002)***	-.0007 (.0002)***
Experience	.104 (.015)***	.105 (.015)***	.289 (.005)***	.290 (.005)***	.290 (.005)***
Experience ²	-.003 (.0005)***	-.003 (.005)***	-.012 (.0003)***	-.012 (.0003)***	-.012 (.0003)***
Tenure	-.897 (.022)***	-.899 (.022)***	-.975 (.008)***	-.975 (.008)***	-.975 (.008)***
Tenure ²	.031 (.0008)***	.031 (.0008)***	.034 (.0003)***	.034 (.0003)***	.034 (.0003)***
Sex	.018 (.048)	.018 (.048)	.147 (.015)***	.147 (.015)***	.147 (.015)***
University Degree	-.045 (.045)	-.045 (.045)	.029 (.016)*	.029 (.016)*	.029 (.016)*
Regional Share HQ	.953 (.874)	13.2 (3.87)***	1.75 (.726)**	2.33 (.835)***	5.76 (2.53)**
Regional Share HQ ²	-	-47.8 (15.0)***	-	-	-9.52 (6.80)
Regional No of Workers	.008 (.004)*	.062 (.020)***	-	-.014 (.009)	-.043 (.045)
Regional No of Workers ²	-	.000003 (.0000007)***	-	-	.0000008 (.000001)
Year Dummies	No	No	Yes	Yes	Yes
Region Dummies	No	No	Yes	Yes	Yes
Sample	Sample I, All Workers in 2000 Staying in a Region	Sample I, All Workers in 2000 Staying in a Region	Sample II, All Workers Staying in a Region	Sample II, All Workers Staying in a Region	Sample II, All Workers Staying in a Region
Adj. R ²	.49	.49	.46	.46	.46
No. of Observations	18,409	18,409	155,272	155,272	155,272

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors of Regional No of Workers, as well as of squares thereof, are multiplied by 1,000; the education variable equals 0 for 'Degree from a Technical College' and 1 for 'Degree from a University'; the variable on a worker's sex equals 0 for 'Male' and 1 for 'Female'.

Table IV – When Does Regional Human Capital Influence Job Change Decisions?

Dependent Variable:	Occurrence of Job Change, by Number of Change				Total Number of Job Changes
	(I)	(II)	(III)	(IV)	
Regional Share HQ	2.45 (1.09)**	1.39 (1.32)	1.45 (2.26)	2.03 (3.33)	-4.38 (2.10)**
Regional No of Workers	-.015 (.012)	-.0001 (.015)	.007 (.027)	.014 (.043)	.047 (.021)**
Year Dummies	Yes	Yes	Yes	Yes	Yes
Region Dummies	Yes	Yes	Yes	Yes	Yes
Sample	Sample II, All Workers Staying in a Region	One Observation per Worker, Workers Staying in a Region, Sample II			
Number of Change	1 st Change	2 nd Change	3 rd Change	4 th Change	-
Number of Changers	6,814	2,417	841	450	-
Pseudo R ²	.59	.30	.33	.36	.073
No. of Observations	151,564	153,199	147,841	131,762	23,187

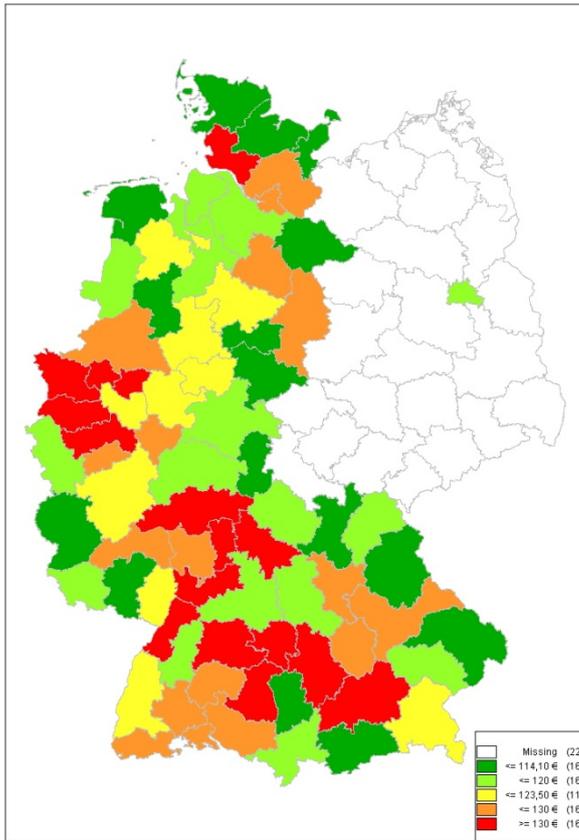
Notes: Results in columns I to IV are based on Probit regressions; Tobit regressions in Column V are bounded by 0 and 4; standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors for Regional No of Workers as well as for squares thereof are multiplied by 1,000; control variables not listed in the table are Sex, Age, Age (squared), experience, experience (squared), tenure, tenure(squared), and education for Columns I to IV, and Sex and Education for Column V.

Table V – Do Workers Change Industries More/Less Frequently in Human Capital Intensive Regions?

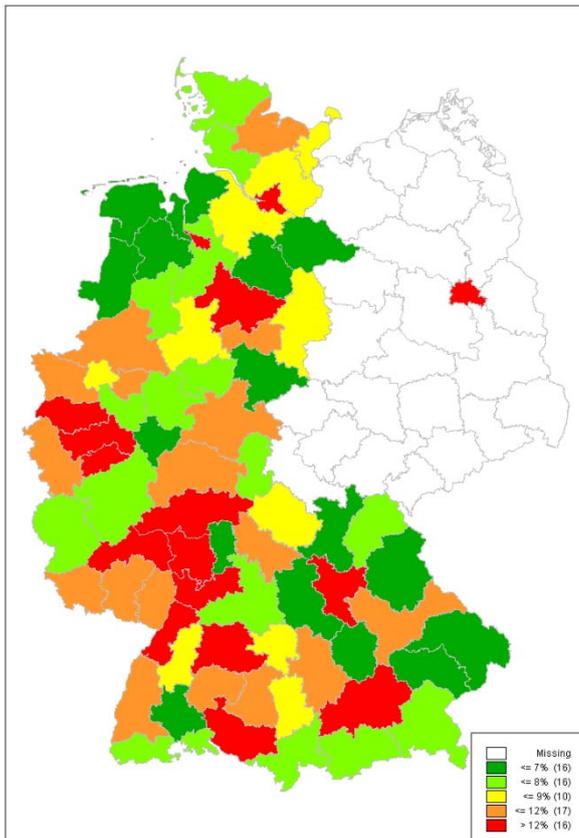
	Dependent Variable: Incident of Industry Change, Conditional on Job Change			
	(I)	(II)	(III)	(IV)
Age	-.006 (.051)	-.037 (.031)	-.011 (.028)	-.012 (.028)
Age ²	.00006 (.0006)	.0004 (.0005)	.00007 (.0004)	.00076 (.0004)
Experience	-.040 (.029)	.015 (.012)	.012 (.011)	.009 (.011)
Experience ²	.0004 (.001)	-.001 (.0006)**	-.001 (.0005)**	-.001 (.0005)*
Tenure	-.072 (.056)	-.035 (.022)	-.041 (.020)**	-.047 (.021)**
Tenure ²	.005 (.004)	-.002 (.001)	.003 (.001)**	.004 (.001)***
Sex	.145 (.088)*	-.028 (.031)	-.021 (.029)	-.026 (.029)
University Degree	.057 (.080)	-.036 (.031)	-.002 (.029)	-.003 (.029)
Regional Share HQ	-2.13 (.996)**	-4.02 (1.51)***	-4.11 (1.29)***	-
Regional No of Workers	-	-	.032 (.018)*	.032 (.018)*
First Move	-	-	-	-.180 (.190)
Second Move	-	-	-	-.150 (.197)
Third Move	-	-	-	-.176 (.224)
First Move*Regional Share HQ	-	-	-	-4.14 (1.31)***
Second Move* Regional Share HQ	-	-	-	-4.21 (1.39)***
Third Move* Regional Share HQ	-	-	-	-3.38 (1.59)**
Fourth Move* Regional Share HQ	-	-	-	-5.04 (1.86)***
Year Dummies	No	Yes	Yes	Yes
Region Dummies	No	Yes	Yes	Yes
Sample	Job Changers within Regions, Sample I	Job Changers within Regions Sample II	Job Changers within Regions Sample II	Job Changers within Regions Sample II
Pseudo R ²	.025	.071	.071	.072
No. of Observations	1,143	10,522	10,522	10,522

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors of Regional No of Workers as well as of squares thereof are multiplied by 1,000; reference groups for move dummies is 'Fourth or More Moves'; the education variable equals 0 for 'Degree from a Technical College' and 1 for 'Degree from a University'; the variable on a worker's sex equals 0 for 'Male' and 1 for 'Female'.

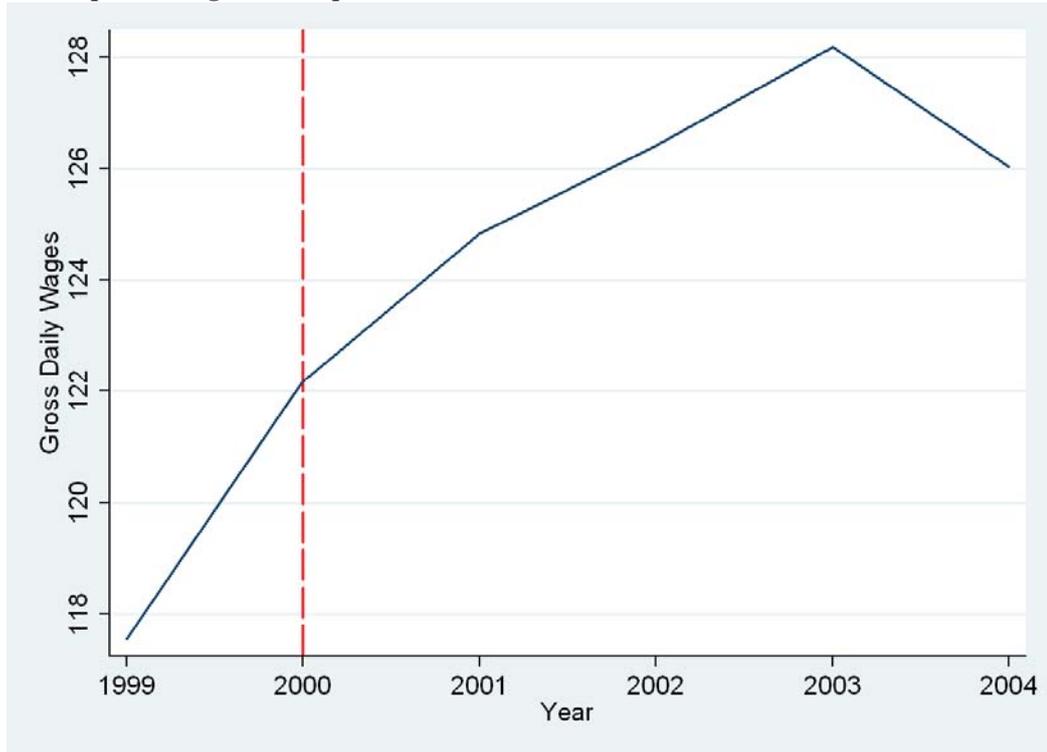
Map I: Average Regional Wages of Highly Qualified Workers, 2001



Map II: Regional Share of Highly Qualified Workers, 2001

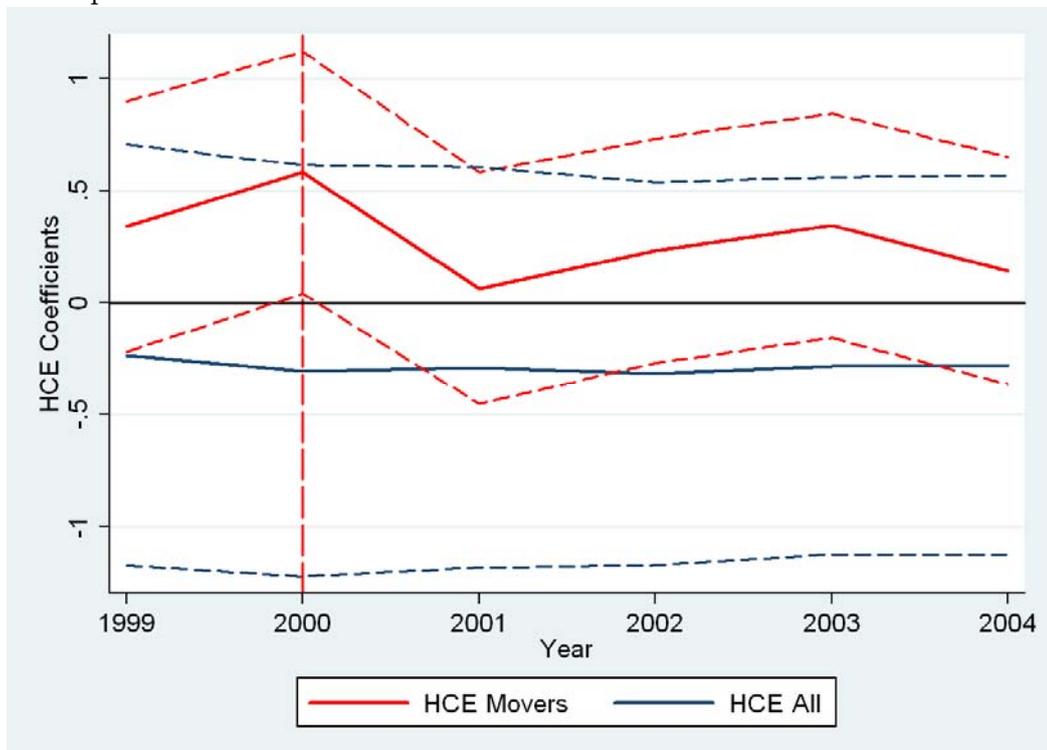


Graph I: Wage Development of Job Movers



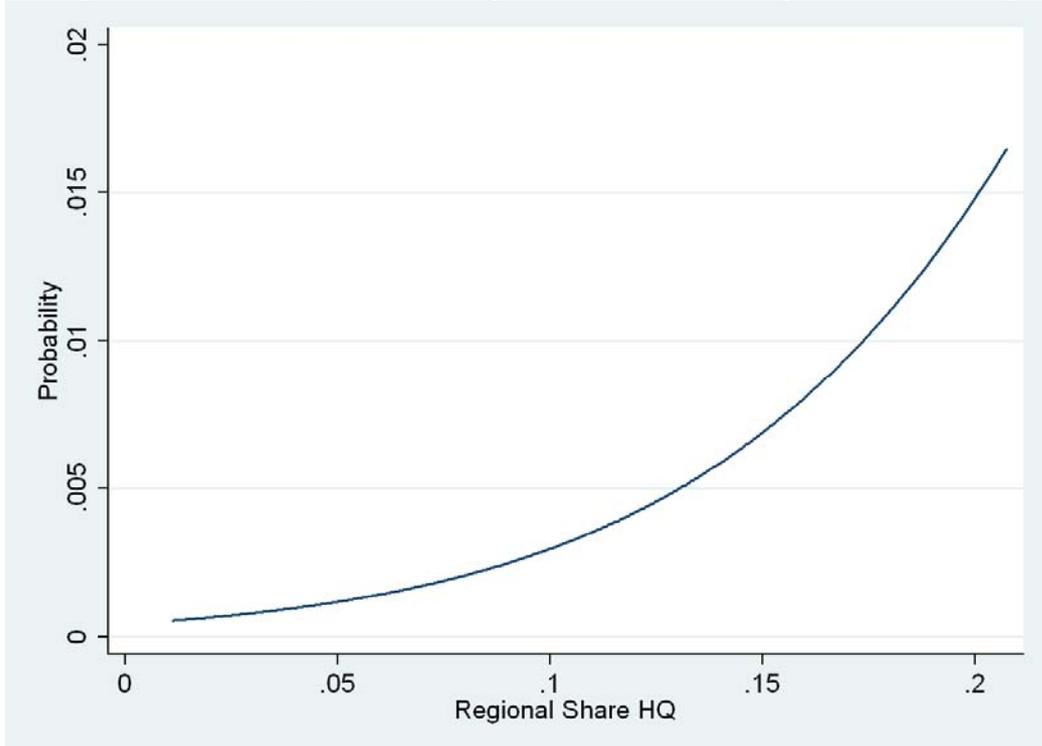
The graph displays annual average wages of all individuals in sample I moving jobs in 2000.

Graph II: Coefficients and Confidence Intervals



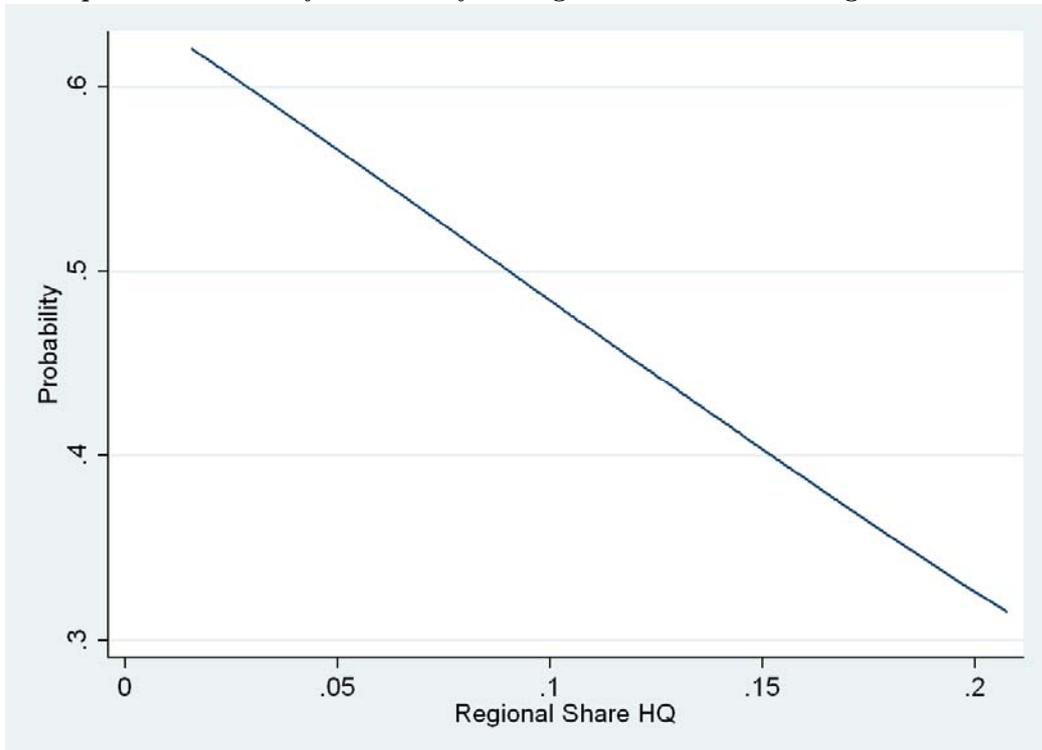
The graph displays the coefficients and the 95 percent confidence intervals of the estimates on the size of general and mover-specific human capital externalities shown in column V in Table I.

Graph III: Probability of Job Change as a Function of Regional Human Capital



The graph displays the results from a simulation of job changing probability as a function of regional human capital endowments, based on the results contained in Column IV in Table III.

Graph IV: Probability of Industry Change as a Function of Regional Human Capital



The graph displays the results from a simulation of industry changing probability of job changers as a function of regional human capital endowments, based on the results contained in Column III in Table V.

Reinventing the Skilled Region: Human Capital Externalities and Industrial Change

Abstract

Bridging the gap between the literatures on industrial change and human capital externalities we investigate the complementarity between aggregate regional education and job turnover. On the level of regional industries in Germany we find strong evidence for such complementarity. Thus, regional human capital turns out to be a crucial ingredient for productivity enhancing industrial change, while human capital externalities arise first and foremost in dynamic labor markets. On the firm level, we find human capital externalities to accrue predominantly to growing firms which benefit from sharing, matching, and learning externalities arising from a large supply of highly qualified workers in skilled, dynamic labor markets. Despite the joint impact of human capital and industrial change on productivity, we find only weak evidence that sectoral differences in the job turnover of highly qualified workers shape the geography of industry location across regions.

Keywords: Human Capital Externalities, Job Turnover, Industrial Change
JEL Categories: D62, J24, R11, R12

I. Introduction: Human Capital Externalities and Industrial Change

“In all of its period of reinvention, Boston’s human capital has been critical. [...] Boston’s experience certainly suggests that human capital is most valuable to a city during transition periods, when skills create flexibility and the ability to reorient towards a new urban focus.”

Edward L. Glaeser (2005: 122)

Understanding why some regions prosper while others decline has occupied urban and regional economists for centuries (see Duranton 2008). Economic investigations of the matter go back to von Thünen (1826) and Weber (1909), who were the first to provide systematic evidence that transportation costs are among the determinants of the attractiveness of a region as a location for economic activity. While the idea that location and distance matter for the economic fate of regions has regained prominence with the seminal contribution by Krugman (1991), it has been increasingly recognized that with transportation costs falling steadily in the age of globalization there must be more to locational attractiveness than infrastructure alone. It was against this background that Edward Glaeser in the mid-1990s inspired a debate on the role of education as a factor for regional growth. Since then, a burgeoning literature starting with Glaeser/Scheinkman/Shleifer (1995) has provided evidence that a broad human capital base is a crucial ingredient for the success of regions as measured by the growth of regional employment (Simon 1998, Simon/Nardinelli 2003, Shapiro 2006). Based on this insight, a closely related literature argues that skilled regions grow faster because aggregate human capital allows them to efficiently adjust to economic shocks through constant industrial change (Glaeser/Saiz 2003). Consequently, in his enquiry into how Boston managed to not only survive the changing economic tides of history, but even to arise as one of the world’s most thriving cities, Glaeser (2005) emphasizes that it was the broad skill base that allowed the city to frequently adjust to new challenges and to live up to the constant demand for industrial change. While emphasizing the importance of human capital for regional growth, this literature is not very precise on the mechanisms through which human capital allows regions to continuously adjust their industrial portfolio so as to foster growth.

A series of studies inspired by Rauch (1993) investigates the existence of social returns to human capital in greater detail. This literature, which is surveyed in Davies (2002) and Moretti (2004a), employs individual wage equations and shows that productivity enhancing effects from aggregate education are substantial. External effects from human capital have been found to increase productivity within regions and industries alike. Rosenthal/Strange (2008) show that human capital externalities are highly localized and decay with distance, while Kirby/Riley (2008)

provide evidence for the existence of human capital externalities within industries. While quantifying the role of local skills for regional and sectoral productivity, studies in this branch usually do not discuss the importance of labor market dynamics and industrial change for human capital externalities to arise.

In this paper we argue that human capital externalities and productivity enhancing industrial change are, in fact, two sides of the same coin. More specifically, we show that while human capital externalities are a crucial ingredient for industrial change to spur regional growth, external effects from education only arise in dynamic regional labor markets. Surprisingly, this complementarity between aggregate human capital and industrial change has until now not been made explicit.

In this paper we close this gap by analyzing productivity effects from aggregate human capital in a framework of dynamic labor markets. We first survey the two strands of the literature in Section II. We then examine the complementarity between aggregate education and industrial change on three different levels of aggregation. Taking industries within regions as our unit of observation in Section III, we investigate whether regional human capital and job turnover unfold productivity effects only conditional on their joint presence. In Section IV we shift focus to the firm level and analyze whether the size of productivity effects from employment adjustments within firms depend on the local turnover of highly qualified workers. In Section V we finally examine whether the complementarity between industry-specific human capital and job turnover influences the spatial distribution of industries.

Our findings from all three modes of investigation yield strong support for regional human capital externalities and industrial change being highly interdependent phenomena. Thus, productivity benefits from industrial change turn out to be strongest if such change takes place within a skilled environment. Human capital externalities, in turn, yield productivity effects predominantly in local labor markets characterized by high levels of job turnover. Productivity effects from the interplay between human capital externalities and industrial change are reflected on the firm level. We find that growing firm in dynamic labor markets benefit from human capital externalities arising from a large turnover of highly qualified workers. On the industry level, we provide evidence that the dynamics of job turnover differ between industries. Contrary to theoretical expectations, such differences only weakly influence the location decision of firms. In sum, our findings suggest that the interplay between human capital externalities and industrial change increases wages within regional industries, contributes to higher productivity of expanding firms, and, to a minor extent, shapes the geography of industrial location across regions.

II. The Mutual Dependence of Skills and Change: Literature and Data

II.1. The Role of Aggregate Education for Successful Regional Change

The idea that regions are under constant pressure to reinvent themselves goes back to Jacobs (1969), who in *The Economy of Cities* describes in detail the ongoing change of urban industrial composition arising from constant innovation and differences in success therein.¹ Jacobs's insight that regional prosperity can be regarded as a function of successful industrial change has regained prominence recently in theoretical models relating regional growth in employment and income to the underlying industrial composition and especially to changes therein. Duranton (2007) provides empirical evidence that while regions grow or decline rather slowly over time, industries tend to move very quickly between regions. In his theoretical model, which is based on this observation, Duranton relates the direction of city growth to the change of industries between locations and shows that small innovation driven shocks can substantially alter the distribution of industries between regions. The crucial insight from this model is that urban evolutions are the result of constant processes of regional innovation and subsequent industry churning. Similarly, Blien/Sanner (2006) and Desmet/Rossi-Hansberg (2009) argue that the maturity of industries located within a region determines overall regional productivity and employment growth. Since growth prospects of industries decline over time, the success of regions lies in their potential to attract young and growing industries.

If the economic success of regions is, in effect, a function of their ability to change their industrial structure, what determines the potential of a region to constantly reinvent itself through industrial change? Jacobs relates successful industrial change to a broad and diversified mixture of sectors and industries. This idea has, in turn, inspired a large literature on whether industrial diversity is conducive to long-term regional growth. Today, empirical evidence supports the notion of nursery cities developed by Duranton/Puga (2001), i.e. while innovation and the birth of industries take place first and foremost in large, diversified cities, industries tend to disperse geographically over time in order to economize on congestion costs. Glaeser et al. (1992) and Combes/Magnac/Robin (2004) find empirical evidence that industrial diversification is conducive to employment growth, while Henderson/Kuncuro/Turner (1995) show that innovation predominantly takes place in diversified regions (see Duranton/Puga 2000 for a survey of the literature).

¹ On the firm level this idea goes back to Chinitz (1966: 6), who famously states that “in a dynamic economy – i.e. rapid change in technology and demand – a major challenge to entrepreneurship is the conversion of old resources to new uses”.

One of the underlying reasons for the success of regional diversification in fostering innovation and growth is that spatial proximity of different industries allows for more intense spillovers of skills and ideas. Analyzing the location patterns of industries, Ellison/Glaeser/Kerr (2007) show that the tendency of industries to coagglomerate is partly driven by the opportunity to exchange ideas, as evidenced by the intensity of regional technology and patent flows. Similarly, Kolko (2008) provides evidence that the co-agglomeration of service industries is driven by knowledge spillovers between different service sectors. With respect to role of aggregate education, these studies indicate that human capital externalities are more likely to arise in diversified regions, since in such environments industries are more likely to learn from each other and thereby be able to quickly react to new challenges by adjusting production and employment. Accordingly, Fu (2007) refers to diversified, skill intensive cities as 'smart café cities'.

The idea that human capital is a driving force for innovation and change has received attention at least since Theodore Schultz's influential contribution on *The Economic Value of Education*, where with respect to external effects from education he states that "schooling increases the capability of people to adjust to changes in job opportunities associated with economic growth" (1963: 40). Moreover, in line with Nelson/Phelps (1966), Welch (1970: 38) emphasizes that "one dimension of education is the ability to adjust to changing conditions and another dimension may be the ability to innovate". Analogously, employing a model of endogenous growth based on Lucas (1988), Aghion/Howitt (1992) argue that economic growth arises from processes of creative destruction, the intensity of which depends on the size of the skilled labor force. In line with this idea, Faberman (2002, 2007) provides empirical evidence that aggregate job turnover increases with regional human capital endowments, indicating that industrial change and the intensity of adjustment rise with aggregate levels of education. Despite a broad consensus on the importance of human capital for successful industrial change and employment growth, the question of whether aggregate education supports successful industrial change first and foremost in growing or in declining regions has remained controversial. Glaeser/Saiz (2003) argue that a broad human capital base yields benefits first and foremost for declining regions, since it allows for successful industrial change through innovation and thereby over time positively influences the direction of growth. In contrast, Findeisen/Südekum (2008) find that human capital is a key driver of growth and industrial change only in successful cities, while regional decline is, in contrast, driven by the demise of old industries which can hardly be altered by human capital endowments of whichever intensity.

The studies surveyed so far provide an answer to one of the most fundamental questions within urban economics, i.e. why some regions are successful while others are not, by relating regional success to human capital endowments, which allow for constant regional adjustment through industrial change. This branch of the literature does, however, not provide evidence on the magnitude of external productivity effects from human capital, nor does it shed light on the microeconomic mechanisms through which they arise. Shifting the focus from the regional to the individual level, the literature on human capital externalities addresses the question of how benefits from the local density of human capital come about.

II.2. The Role of Dynamic Labor Markets for Human Capital Externalities

Complementing the literature on the importance of regional human capital endowments for industrial change and regional growth, a series of studies resort to individual wage equations in order to more thoroughly investigate the existence of social returns to human capital. Earlier studies, e.g. by Rauch (1993), argue that increasing average regional levels of education, as measured by average years of schooling, by one year raises regional wages by five percent due to social returns from education. More recent investigations employing the share of highly qualified workers as a measure of aggregate education show that increasing the share of highly qualified workers by one percent raises aggregate wages by between .4 and 1.9 percent due to external effects from human capital (see Moretti 2004b, Fu 2007).

Studies in this branch of the literature have traditionally associated external effects of human capital with spillovers of technological knowledge. However, there might be more to human capital externalities than the exchange of information on products and processes of production alone. In fact, Duranton (2006) points out that the microeconomic mechanisms through which social returns to human capital come about might be similar to those underlying benefits from agglomeration. Consequently, the class of microeconomic models which explain how productivity benefits arise from economic density can be regarded as a natural starting point for any enquiry into the sources of human capital externalities. Since Duranton/Puga (2004), such models are usually categorized along the lines of sharing, matching, and learning as the core mechanisms through which productivity enhancing agglomeration externalities come about. Analogously, regional human capital can be expected to increase regional productivity through improved opportunities for learning about innovation in products and modes of production, through more efficient matches between workers and firms, and through the sharing of employment risk due to higher worker mobility. We briefly explain these mechanisms in turn.

As argued in the theoretical literature on knowledge transmission, increasing the level of skills within a population allows for an improved exchange of ideas and thereby increases the potential for innovation and economic growth (Jovanovic/Nyarko 1995). The importance of local human capital endowments for the intensity of knowledge spillovers has been confirmed by a broad empirical literature on the geography of innovation (see Audretsch/Feldman 2004 for an overview). In addition to facilitating the exchange of technical knowledge, aggregate levels of human capital improve the diffusion of information on labor market opportunities and thereby enhance the quality of job matches between workers and firms (Heuermann 2009). In fact, the size of social networks and therewith the efficiency of information diffusion have been shown to increase with individual education (Grossetti 2007). Consequently, human capital externalities through matching arise because aggregate education increases the size of networks and thereby enhances the diffusion of information within local career networks. Finally, firms in regions shaped by higher aggregate education are able to share the risk of employment shocks more efficiently because skilled workers can change jobs between industries more easily than unskilled workers due to a higher level of general skills (Borjas 1987, Chiswick 2005). Having access to a larger stock of highly qualified workers allows firms to efficiently adjust employment to changing levels of demand or productivity and thereby avoid search or vacancy costs. Thus, human capital externalities might arise from an improved intensity of knowledge spillovers, the diffusion of labor market information in dense career networks, and the opportunity of firms to adjust to efficient levels of employment in the face of productivity or demand shocks.

A closer look at these microeconomic mechanisms reveals that the extent to which human capital externalities shape regional wages and productivity is not only a function of aggregate levels of human capital, but also of the intensity of change within regional labor markets. More precisely, job changes of highly qualified workers are a prerequisite for productivity effects from aggregate human capital to unfold. In fact, Saxenian (1994) and Almeida/Kogut (1999) show that knowledge is transferred between firms mostly by workers changing jobs from one firm to another. Thus, knowledge spillovers increase with the churning intensity of highly qualified workers. Likewise, productivity effects from improved labor market matching ultimately depend on the number of workers taking the opportunity to change jobs. In fact, Heuermann (2009) provides evidence that workers in skilled regions not only incur higher wage gains when changing jobs, but also change jobs more often early in life. Finally, benefits from risk sharing in skilled regions arise only if qualified workers are more likely to change jobs between industries and thereby allow firms to adjust employment more efficiently. Providing indirect evidence on risk sharing effects in agglomerated regions, Overman/Puga (2008) show that firms which adjust

employment benefit from the intensity to which neighboring firms adjust employment in the opposite direction. Thus, each of these microeconomic sources requires dynamic local labor markets as a prerequisite for productivity enhancing effects from aggregate human capital to come about.

In what follows we investigate the complementarity between aggregate levels education and dynamic local labor markets on three different levels. After describing the data, we first investigate whether productivity in local industries increases with the joint presence of local human capital endowments and dynamic labor markets. We then analyze whether firms benefit from high levels of job turnover in human capital intensive regions when adjusting employment. On the level of industries, we finally examine whether the prevailing distribution of industries across regions can be explained by differences in intra-industry job turnover of highly qualified workers.

II.3. Data and Descriptive Evidence

All subsequent analyses are based on the Establishment History Panel (BHP) provided by the Institute for Labor and Employment Research (IAB). The BHP is generated by aggregating information on all employees in Germany contained in the Social Security File of the Federal Employment Agency to the establishment level. The resulting dataset covers all establishments in Germany between 1975 and 2005 which employ at least one employee subject to social security contributions (see Spengler 2007 for an overview of the data).² The annual number of establishments in the dataset, defined as a plant or, more generally, a place of work, ranges between 1.5 and 2.5 million.³ For these establishments the dataset contains information on location, industry affiliation, and employment and wage structure, with each variable being observed once a year on the 30th of June. From the annual waves we have generated a panel dataset which allows for tracking establishments over time.

Using information on industrial affiliation we have grouped firms into 18 different sectors, a list of which can be found in Table I along with further information on sectoral employment and payment structures. We define labor market regions along the lines of the 75 '*Raumordnungsregionen*' defined by the Federal Office for Building and Regional Planning, which are equal to NUTSII regions (BfLR 1996). While these regions are not explicitly defined so as to reflect workers' commuting behavior, they do, by principle of construction, always cover a core city and its surrounding periphery (Kosfeld/Eckey/Türck 2006).

² Although technically we are dealing with establishments throughout the empirical analysis, in what follows we use the terms establishment and firm interchangeably for reasons of simplicity.

³ See Fritsch/Brixey (2004) for a discussion on the definition and classification of establishments.

In all our analyses we measure regional, sectoral, and firm productivity as the average wage of highly qualified workers, defined as those workers holding a degree from either a university or a technical college, rather than as the average wage of all workers. A number of reasons have convinced us to focus on highly qualified workers alone. First, wage setting is more flexible for highly qualified workers, who are less likely to be bound by wage agreements. Focusing on highly qualified workers therefore allows for uncovering regional productivity differences between industries, which are otherwise prone to be suppressed by wage leveling institutional arrangements. Closely related, since we wish to shed light on the importance of change in the labor market, we assume that workers and firms are able to change jobs or employment without such adjustments being delayed, altered, or impeded by labor market institutions. While the German employment protection legislation in principle covers all workers alike, highly qualified workers in practice draw less on such legislation since they usually find it easier to change jobs between firms. Finally, since Ciccone/Peri (2006) it is well known that imperfect substitutability between highly qualified and non-highly qualified workers might bias estimates on the existence of human capital externalities, because due to supply and demand effects an increase in the regional share of highly qualified workers depresses wages of highly qualified workers while increasing those of non-highly qualified workers. Since the supply of highly qualified workers increases over time we are prone to overestimate effects from human capital externalities when not differentiating their effects by qualification. Since the primary objective in this paper is to provide first evidence on the interplay between regional change and human capital externalities, we have decided to focus on highly qualified workers alone, well aware that doing so we are likely to underestimate the social returns to education and thereby the joint importance of human capital externalities and job turnover for productivity.

We employ the regional share of highly qualified workers as our preferred measure of regional human capital, rather than average levels of education. Doing so, we follow Krueger/Lindahl (1999) and Moretti (2004b) in their argument that external productivity effects through sharing, matching, and learning are predominantly rooted in the share of highly qualified workers, while external effects from average levels of education unfold predominantly through non-market externalities, such as reductions in crime rates or improved health related behavior.

Maps I and II provide evidence on the close correlation between the regional share of highly qualified workers and average regional wages earned by highly qualified workers across the 75 regions in Western Germany. High average wages and human capital endowments follow an imaginary line from the North-West to the South-East. Heuermann (2008) provides evidence on the importance of human capital

externalities as a determinant of wages across the regions in Western Germany. Employing the regional number of students and the number of schools as instrumental variables for the regional share of highly qualified workers, he shows that while sorting effects play a role for higher wages in skilled regions, external effects from human capital raise wages of highly qualified workers by 1.8 percent with each additional percent in the share of highly qualified workers. Thus, a one standard deviation in the regional share of highly qualified workers is associated with an increase in wages of about eight percent. In the following analysis we investigate the extent to which dynamic labor markets are a prerequisite for such productivity enhancing effects from aggregate human capital to arise.

III. The Symbiosis between Human Capital and Industrial Change

In this section, we investigate whether the productivity of regional industries rises with the joint presence of industrial change and aggregate human capital. We address this question by examining whether the interaction between human capital endowments and job turnover enhances productivity within regional industries. Equating industrial change with job turnover in regional industries is subject to the assumption that the intensity of industry specific change is reflected in the adjustment dynamics of intra-industry labor markets, i.e. we assume that the extent to which industries change directly translates into employment adjustments.⁴ In line with the existing literature, job turnover is defined as the sum of job creation and destruction within regional industries. Thus, an observed sectoral job destruction rate of ten percent in a regional industry combined with a job creation rate of fifteen percent would imply an overall intensity of change within a regional industry of twenty-five percent. Given our definition, we would obtain the same result with a job destruction rate of twenty five and a job creation rate of zero percent. Thus, focusing on the sum of job creation and destruction we generally interpret any type of employment adjustment as being indicative of industrial change without conceptually distinguishing between contraction, expansion, or internal churning of industries. We do, however, for reasons of robustness differentiate between types of adjustments in the course of our empirical analysis below.

In line with Davis/Haltiwanger/Schuh (1996), we define the job creation rate in region r in sector s at time t as the sum of jobs created by all firms i in sector s in

⁴ Although widely used, job turnover is not the only indicator for industrial change. In line with Jovanovic (1982), the turnover of firms is an alternative indicator for the intensity of industrial change (see Santarelli/Vivarelli 2007 for an overview of the literature of industry evolution and firm turnover).

region r at time t as a share of the average employment in sector s in region r between time t and $t-1$.

$$JC_{r,s,t} = \frac{\sum_i \Delta E_{i,r,s,t}^+}{\sum_t \frac{E_{i,r,s,t} + E_{i,r,s,t-1}}{2}} \quad (1)$$

Analogously, we define the region-sectoral job destruction rate as the absolute sum of jobs destroyed by all firms i in region r in sector s at time t as a share of average past and present region-sectoral employment.⁵

$$JD_{r,s,t} = \frac{\sum_i |\Delta E_{i,r,s,t}^-|}{\sum_t \frac{E_{i,r,s,t} + E_{i,r,s,t-1}}{2}} \quad (2)$$

The region-sectoral gross job reallocation rate equals the sum of region-sectoral job creation and destruction weighted by average region-sectoral employment (Davis/Haltiwanger 1992, 1999).

$$GJR_{r,s,t} = \frac{\sum_i |\Delta E_{i,r,s,t}^-| + \sum_i \Delta E_{i,r,s,t}^+}{\sum_t \frac{E_{i,r,s,t} + E_{i,r,s,t-1}}{2}} \quad (3)$$

Graph I to V provide evidence on the size and evolution of national, sectoral, and region-sectoral change intensity. Graphs I and II map the dynamics of job turnover on a national level showing that with about twenty-five percent of jobs being created or destroyed, annual job turnover within the labor market for highly qualified workers in Western Germany is substantial. Expressed in absolute numbers, more than 350,000 of about 1.4 million jobs held by highly qualified workers were turned over in 2003. Of these, about four fifth are reallocated between firms, while the remaining one fifth is due to net job creation. While net job growth has remained roughly constant over time with about 50,000 jobs newly created per year, excess turnover has tripled from about 120,000 jobs being reallocated between firms in 1977 to 350,000 jobs in 2003. Thus, job reallocation between firms is about seven times larger than annual net job growth in 2003. Graph III shows that the bulk of job churning takes place in existing establishments, which create and destruct nearly twenty percent of overall highly qualified employment, i.e. about 280,000 jobs, each year.⁶ This number is distinctly smaller for start ups, closing firms, and up- and

⁵ For reasons of brevity and in order to avoid unnecessary repetition we refer to job creation, destruction, and reallocation in region r in sector s at time t from now on as *region-sectoral* job creation, destruction, and reallocation.

⁶ We define existing establishments as those which have already employed highly qualified workers in the past period and continue to do so in the present period; upgrading firms have already existed in the past period, but employ highly qualified workers for the first time in the present period;

downgrading firms, which together turn over about five percent of national employment of highly qualified workers, i.e. about 70,000 jobs, annually.⁷ Graph IV reveals that job turnover not only differs substantially between sectors, but that these differences are stable over time. While most sectors exhibit annual job turnover rates between fifteen and thirty percent, these rates range well beyond forty percent in Retail, Consumer Services, and Legal and Economic Consulting. Finally, Graph V shows that region-sectoral job creation and destruction rates are positively correlated, implying that the bulk of job churning takes place within regional industries, rather than between them (see Baldwin/Dunne/Haltiwanger 1998). Given our theoretical considerations, these numbers raise the question of whether productivity effects from job reallocation depend on the density of human capital within local or sectoral labor markets. With each job being turned over every four years on average there is clearly room for theoretical arguments that firms and workers benefit from high levels of local human capital by reaping gains from sharing, matching, and learning.

To investigate the complementarity between human capital and industrial change we estimate average productivity within a regional industry as a function of the intensity of job reallocation, human capital endowments, as well as their interaction.

$$w_{r,s,t} = \beta_1 HC_{r,s,t,k} + \beta_2 GJR_{r,s,t,k} + \beta_3 HC_{r,s,t,k} \times GJR_{r,s,t,k} + \beta_k X_{r,s,t,k} + \beta_m Z_{r,t,m} + \phi_r + \phi_s + \phi_t + \varepsilon_{r,s,t} \quad (4)$$

More specifically, we regress average wages w in region r in sector s at time t on the share of highly qualified workers, HC , on the job reallocation rate, GJR , on the interaction between human capital intensity and change, as well as on a number of region-sectoral and regional characteristics, X and Z . On the region-sectoral level we control for average firm size, which has frequently been shown to be related to average wages (Green/Machin/Manning 1996). In addition, we control for agglomeration effects within both regions and regional industries by including the respective numbers of highly qualified workers. In order to account for entity and time invariant factors we employ region, sector, and time fixed effects. Our coefficient of interest is β_3 , which we expect to be significantly positive if productivity effects of regional change and regional human capital are complementary, i.e. arise conditional on their joint presence. For results on the interaction term to be consistent, no variables should exist which are correlated with either industrial change or human capital and unfold productivity effects conditional on the presence of the respective

downgrading firms have employed highly qualified in the last period but ceased to do so in the present period; start-ups/closures start/cease to exist, creating/destroying highly qualified employment (see Boeri/Cramer 1992 for a comparison of differences in growth between incumbents and start-ups).

⁷ Disaggregating gross job turnover into job creation and job destruction by firm type clearly shows that existing firms are the drivers of employment growth, defying Birch's (1987) notion that small start-ups create the lion's share of jobs.

other one. For reasons outlined below, we control for the interaction between the regional rate of unemployment and job turnover as a potentially confounding factor. Doing so, we are confident that despite its ad-hoc nature, this equation lives up to our objective of providing first evidence on the complementarity between aggregate human capital and industrial change. Scrutinizing the robustness of our findings we further investigate this complementarity on the firm level in Section IV.

Table II contains our results. In columns I to IV we estimate equation (4) taking industries within regions as our unit of observation. In column V we focus on the level of overall regions rather than on single industries. Our dependent variable throughout all regressions is the average productivity of highly qualified workers. For reasons of clarity we have grouped the independent variables into four categories. The results on the interaction between job turnover and aggregate human capital are contained in the category *'Skills and Change'*. Results on unconditional effects from both variables are contained in the categories *'Change'* and *'Skills'*. Control variables are contained in *'Controls'*. We comment on the results within each category in turn.

As our core result, we find strong evidence for significantly positive productivity effects from the joint presence of regional change and human capital endowments, which are subject to negative marginal returns. In fact, all interaction effects between the share of highly qualified workers and the intensity of job turnover are positive and highly significant, while their squares turn out significantly negative. More specifically, the coefficient on the interaction term in column II indicates that raising the share of human capital within a regional industry by one standard deviation, i.e. by about ten percent, increases wages by about two percent conditional on an average job turnover rate of 25 percent. Conversely, raising average job turnover by one standard deviation, i.e. by 13 percent, increases wages by about one percent, conditional on an average level of human capital of about eleven percent.

In column III we analyze whether complementarities between industrial change and aggregate human capital mainly occur on the level of regional industries, or on the level of regions. We therefore interact the region-sectoral job turnover with the share of highly qualified workers within a regional industry and within a region, respectively. We find that regional industries not only benefit from their own human capital endowments in times of change, but even more so from the share of highly qualified workers on the regional level. This result indirectly supports the notion that industries in diversified regions are more productive because they benefit from sharing one regional labor market with other industries. In fact, finding the complementarity between aggregate human capital and industrial change to be more pronounced on

the regional level than within local industries suggests that highly qualified workers change jobs between industries more often in skilled regions and thereby allow for external productivity benefits from improved opportunities for matching, sharing, and learning to arise.

The last two columns contain further robustness checks. In column IV we control for nonlinearities in the interaction terms. While the significantly negative coefficients on the quadratic interaction terms evidence marginally decreasing joint effects, the overall joint effect remains positive over the whole range of existing values for turnover and human capital. In column V we examine whether productivity effects found within regional industries also arise within regions. We therefore exchange our dependent variable, i.e. average productivity on the region-sectoral level, with its equivalent on the regional level. Again, the complementarity between human capital and job turnover turns out to be more pronounced on the regional level. This finding emphasizes that in line with Jacobs (1969) the success of regions does not depend on aggregate human capital and industrial change within single industries alone, but rather on the overall sectoral composition of regions and the constant exchange of highly qualified workers between industries.

The unconditional effects of job turnover and human capital on both sectoral and regional productivity turn out to be negative. With respect to industrial change, this indicates that employment reallocation within industries is not in and by itself productivity enhancing. Two reasons come to mind. First, job turnover is likely to entail the loss of firm-specific human capital. Secondly, with the overall number of highly qualified workers increasing by about five percent annually, overall job turnover is partly driven by the net creation of highly qualified employment. This net creation is likely to depress wages through supply effects and through a generally lower labor market experience of young workers. Negative coefficients on the share of highly qualified workers, in turn, indicate that productivity enhancing effects from human capital predominantly arise through labor market dynamics, while overall levels of human capital first and foremost unfold static amenity effects, which in turn depress wages (see Moretti 2008). Alternatively, negative effects from aggregate human capital might result from supply effects rooted in the imperfect substitution between highly qualified and non-highly qualified workers discussed above.

Our control variables display the expected signs and are of a meaningful size. In general, average wages rise with average firm size per sector, as well as with the overall number and the number of highly qualified workers in a sector. In columns II to V we have additionally controlled for wage curve effects, as well as for potential interaction effects between job turnover and region-sectoral unemployment. The

latter is inspired by Moretti (2000), who argues that workers are compensated for the risk of becoming unemployed. Since the risk of becoming unemployed is a function of overall levels of unemployment and job turnover, we include the interaction between both in our equations.⁸ We find evidence for wage curve effects and risk compensation on the regional level. Since a detailed investigation of such insurance effects is beyond the scope of this paper, we leave it for further research.

In Table III we address the question raised by Glaeser/Saiz (2003), i.e. whether aggregate human capital and industrial change yield productivity effects independent of the direction of industrial growth. As outlined above, while Findeisen/Südekum (2008) show that education unfolds external effects only in expanding sectors in Germany, Glaeser/Saiz (2003) provide evidence for the US that human capital is especially helpful in times of sectoral decline. In Columns I to V we re-estimate equation (4), employing net job creation and destruction rates, excess churning rates, and positive and negative job growth rates as indicators for different types of industrial change. Human capital effects turn out to be largest in industries characterized by high rates of excess churning, i.e. if jobs are allocated intensely between firms within a sector, and in industries exhibiting positive job growth and job creation rates. In contrast, we find only small positive effects for industries shaped by high rates of job destruction, and no significant effects from aggregate human capital in declining industries. In line with Findeisen/Südekum (2008) our results suggest that human capital and job turnover are most productively combined in dynamic sectors displaying an overall tendency to grow. Analogous to our analysis above, we find productivity effects from aggregate human capital to be larger on the regional compared to the region-sectoral level.

We draw two preliminary conclusions from our results obtained so far. First, neither industrial change nor regional human capital endowments yield productivity effects in and by themselves. Rather, while successful industrial change necessitates the presence of aggregate human capital, human capital externalities themselves come about only through workers changing firms in dynamic labor markets. Secondly, joint productivity effects from human capital and industrial change primarily depend on aggregate levels of education within regions, rather than within regional industries alone, supporting Jacob's (1969) idea that a broad skill base and a diversified industry structure allows regions to constantly and successfully reinvent themselves.

⁸ We thank Oliver Fabel for pointing out the necessity to control for insurance effects in the face of high rates of both regional unemployment and job turnover.

IV. Human Capital Externalities and Change on the Firm Level

In this section, we wish to corroborate our findings on the complementarity between industrial change and human capital on the firm level by examining whether firms benefit from being located in dynamic and skilled regions when adjusting their employment of highly qualified workers. Our presumption is that if improved opportunities for sharing, matching, or learning exist in skilled, dynamic labor markets, growing firms should incur productivity effects predominantly in regions shaped by a large supply of highly qualified workers.

An example clarifies the idea. Imagine a firm wishes to increase production due to a positive productivity shock by recruiting highly qualified workers. With the existence of local human capital externalities we should find growing firms to benefit from the extent to which neighboring firms reduce their employment, since this allows them to easily find a qualified match (matching externality), to obtain potentially relevant knowledge from neighboring firms (learning externality), and to benefit from lower adjustment costs due to a larger supply of highly qualified workers in shared labor markets (sharing externality).

Based on this idea, we examine whether the productivity of firms which adjust employment is influenced by the intensity to which other firms within the same industry adjust employment in the opposite direction. We therefore define two indicators for the overall adjustment trends within a regional industry, as well as two indicators of the extent to which firms develop either parallel with, or against this trend. We take the absolute value of the region-sectoral growth rate (GR) as indicator for the intensity of employment adjustment within a regional industry.

$$GR_{r,s,t} = \left| \frac{\sum_i E_{i,r,s,t}}{\sum_i E_{i,r,s,t} + \sum_i E_{i,r,s,t-1}} \right| \quad (5)$$

Firms can adjust employment either in line with the overall growth trend of an industry, i.e. expand (reduce) employment in growing (declining) industries, or can develop diametrically. We therefore define one indicator for the intensity to which a firm grows in line with its industry. Our indicator for sector-congruent employment adjustment (SCA) equals the growth rate of a firm if it grows into the same direction as its regional industry, and takes on a value of zero otherwise.

$$SCA_{i,t} = \begin{cases} \left| \frac{E_{i,t}}{E_{i,t}+E_{i,t-1}} \right| & \text{if } \text{sign}\left(\frac{E_{i,t}}{E_{i,t}+E_{i,t-1}}\right) = \text{sign}(GR_{r,s,t}) \\ 0 & \text{if } \text{sign}\left(\frac{E_{i,t}}{E_{i,t}+E_{i,t-1}}\right) \neq \text{sign}(GR_{r,s,t}) \end{cases} \quad (6)$$

Conversely, our indicator for sector-adverse employment adjustment (SAA) measures the deviation of individual firm growth from the growth trend of its regional industry. It is defined as the sum of absolute values of firm level growth and region-sectoral growth if both show opposite signs. If a firm grows into the same direction as the regional industry, the SAA takes on a value of zero. Since a firm can adjust employment only into one direction within a given year (if it grows at all), the SCA and the SAA can never both be different from zero at the same time for one firm.

$$SAA_{i,t} = \begin{cases} \left| \frac{E_{i,t}}{E_{i,t}+E_{i,t-1}} \right| + \left| \frac{\sum_i E_{i,r,s,t}}{\sum_i E_{i,r,s,t} + \sum_i E_{i,r,s,t-1}} \right| & \text{if } \text{sign}\left(\frac{E_{i,t}}{E_{i,t}+E_{i,t-1}}\right) \neq \text{sign}\left(\frac{\sum_i E_{i,r,s,t}}{\sum_i E_{i,r,s,t} + \sum_i E_{i,r,s,t-1}}\right) \\ 0 & \text{if } \text{sign}\left(\frac{E_{i,t}}{E_{i,t}+E_{i,t-1}}\right) = \text{sign}\left(\frac{\sum_i E_{i,r,s,t}}{\sum_i E_{i,r,s,t} + \sum_i E_{i,r,s,t-1}}\right) \end{cases} \quad (7)$$

We finally define an indicator for the average intensity to which firms within a regional industry develop against the sectoral trend. We define this average adverse growth rate (AGR) as the mean sector-adverse adjustment rate within an industry. This indicator measures the average intensity to which N firms in region r in sector s at time t adjust employment opposite to the growth trend of their regional industry.

$$AGR_{r,s,t} = \frac{\sum_i SAA_{i,t}}{N} \quad (8)$$

Based on these indicators we examine whether growing firms are more productive through improved opportunities for sharing, matching, and learning in regional industries which are shaped by a large availability of highly qualified workers. An increased local supply of highly qualified workers can arise from two scenarios. On the one hand, firms expanding employment of highly qualified workers in line with their regional industry, i.e. display non-zero SCA, are expected to benefit from the intensity to which other firms reduce their employment of highly qualified workers against this overall trend, i.e. from the size of the AGR. Conversely, firms which grow while their local industry declines in terms of highly qualified employment, i.e. which display a non-zero SAA, should incur productivity benefits from the intensity of local industrial decline.

Investigating the productivity consequences of these two types of adverse adjustments dynamics between firms and their local industries, we estimate equation (9), which

expresses the average wage in firm i at time t , $w_{i,t}$, as a function of the interactions between region-sectoral growth and sector-adverse firm adjustment, and between average adverse adjustment and sector-congruent firm growth.

$$w_{i,t} = \beta_1(GR_{r,s,t} \times SAA_{i,t}) + \beta_2(AGR_{i,t} \times SCA_{r,s,t}) + \beta_3 GR_{r,s,t} + \beta_4 SCA_{i,t} + \beta_5 SAA_{i,t} + \beta_6 AGR_{r,s,t} + \gamma_k Z_{k,i,t} + \phi_i + \phi_r + \phi_s + \phi_t + \varepsilon_{i,t} \quad (9)$$

β_1 and β_2 provide evidence on whether human capital externalities arise from the interplay between firm-level employment adjustments and the availability of highly qualified workers within regional industries. A significantly positive coefficient β_1 indicates that productivity benefits accrue to growing firms in regional industries which decline in terms of highly qualified employment. Conversely, a significantly positive coefficient β_2 provides evidence that firms which in line with their regional industry exhibit positive growth rates benefit from the intensity to which other firms shed highly qualified workers. Significant coefficients of either type reinforce the notion that the reallocation of highly qualified workers between firms provides the basis for productivity effects from human capital to arise on the microeconomic level.

In order to control for unconditional productivity effects from employment adjustment on the firm and industry level, we include each of our four indicators separately. Since wages increase with firm size and with the level of qualification within a firm, we also control for total employment, as well as for the share of highly qualified workers within a firm (see Holmes/Stevens 2002). In order to control for factors which are constant across time or entities we include region, sector, time, and firm fixed effects. As in Section III, our identifying assumptions is that no variables exist which are correlated with firm-level (region-sectoral) employment adjustment and unfold productivity effects conditional on region-sectoral (firm-level) employment dynamics. While we cannot completely rule out the possibility that such variables exist, we deem this approach suitable to complement the evidence obtained in Section III and to provide first evidence on the role of firm level and region-sectoral employment adjustment dynamics for human capital externalities to arise.

We estimate equation (9) on different subsamples. Comparing the effects for firms which expand employment to those which reduce employment, we examine whether in line with our theoretical expectations interaction effects are driven first and foremost by growing firms. In addition, estimating the equation separately for growing and declining sectors allows us to control for wage effects arising from differences in labor supply and demand within regional industries.

Table IV contains our results. For reasons of clarity we have again grouped the independent variables into three categories. The first category, '*Adverse Change*', provides results on the interaction terms. The categories '*Industrial Change*' and '*Controls*' contain unconditional wage effects from firm and industry level employment adjustments, as well as results on further control variables. In the first column we have estimated equation (9) using the full sample of firms. Columns II to V display our results obtained from different subsamples of sectors and firms.

Results within the category '*Adverse Change*' reveal a clear-cut pattern. Significantly positive coefficients in column I provide evidence that the productivity of firms which adjust employment increases with the intensity to which other firms adjust their employment in the opposite direction. Columns II and III show that such productivity effects from adverse adjustment are entirely driven by growing firms. This finding is in line with our theoretical proposition that human capital externalities accrue mainly to growing firms which benefit from sharing, matching, and learning externalities rooted in the improved local availability of skilled workers.

The first line in column II shows that if firms grow with their industry by an annual average of seventeen percent, increasing the average adverse adjustment intensity by one standard deviation, i.e. by five percentage points, is associated with .1 percent higher wages. Conversely, increasing firm growth by one standard deviation, i.e. by about forty percentage points, raises average wages of highly qualified workers by .6 percent, given an average region-sectoral adverse adjustment intensity of thirteen percent. Since in order to avoid further complication we do not control for productivity effects which arise only over time, the wage gains observed here are likely to be incurred predominantly by job changers. Given this reasoning, our results suggest that human capital externalities raise wages of those seventeen percent of workers who start jobs in growing firms by .5 percent on the incidence of job change.

The second line in column I shows that similar effects can be found for firms which grow against the trend of their local industry. However, comparing both results reveals that productivity gains from adverse adjustments are significantly larger for firms which grow with their industry, than for those growing against it. Since there is no theoretical reason why human capital externalities should accrue differently to either type of firm, we suspect that differences in labor supply and demand within regional industries might drive our results.

In Columns IV and V we therefore estimate equation (9) separately for growing and declining sectors. We find only minor differences. In fact, whenever firms grow, they

benefit from adverse adjustments of their regional industry. For shrinking firms, in contrast, we find no effects in Column IV and rather small effects in Column V. In general, the results in Table IV indicate that productivity effects from the interaction between firm growth and adverse employment adjustment within regional industries arise for growing firms independent of whether they grow with their sector or against it. Thus, while we are unable to explain why human capital effects are of a different size for the two types of firms, our results do not differ between growing and contracting sectors and are thus unlikely to be driven by supply and demand effects.

Before interpreting this result in the light of the interdependence between human capital and industrial change, the coefficients on unconditional effects from industry and firm level adjustments, as well as on further controls deserve brief mentioning. We find both industry and firm turnover to be negatively related to firm productivity. In line with our argumentation from Section III, we relate negative productivity effects from aggregate change within regional industries to an overall loss of firm specific human capital. The same argument holds for negative effects from firm-specific turnover, which brings about lower levels of firm- or industry-specific human capital and, given an increasing supply of highly qualified workers, a higher average number of young, inexperienced workers within firms. The results on further control variables are in line with our expectations. Cubic specifications of firm size and firm-specific human capital endowment showed the best fit, indicating that both are correlated with higher average firm wages.

Summing up, our results provide evidence that growing firms are more productive when having access to highly qualified workers within dynamic and skilled labor markets, suggesting that human capital externalities arise from the intensity of employment adjustment in skilled regions. This result, which emerges consistently across growing and declining sectors, corroborates the complementarity between aggregate education and industrial change identified in Section III. In fact, finding significantly positive interaction effects between firm growth and adjustment dynamics within regional industries supports the idea that the local environment within which firms adjust their employment of highly qualified workers is crucial for productivity enhancing effects from human capital externalities to arise. More specifically, our findings suggest that skilled and dynamic regional industries enable firms to benefit from efficient matches, facilitated knowledge spillovers, and from shared labor markets across industries.

V. The Intensity of Change and the Geography of Industrial Location

Our results obtained so far suggest that productivity enhancing external effects from aggregate human capital come about through highly qualified workers changing jobs in dynamic local labor markets. This raises the question whether firms strategically choose their location so as to benefit from a high local turnover of highly qualified workers. In this section we therefore examine whether differences in job turnover intensities between industries shape the geography of industrial location in Germany.

Based on our result from Section IV, i.e. that firms incur productivity benefits if they have access to dynamic local labor markets, we expect firms within one industry to coagglomerate if they display a high variance of employment adjustment. Conversely, industries exhibiting a low variance of firm growth should be more dispersed geographically in order to reap the gains from regional diversification, i.e. to allow firms to exchange highly qualified workers with firms of other local industries. Hence, the core hypothesis we examine here is whether the potential of firms within one industry to exchange highly qualified workers shapes their propensity to cluster. We test this proposition by investigating whether the extent to which firms adjust their employment parallel to other firms in their sector influences the size of regional industries, as well as the overall concentration of an industry.

We first analyze whether we find evidence that regional industries with a high potential to exchange highly qualified workers between firms are larger on average. As a measure for the potential to exchange highly qualified workers we take the average adverse growth rate defined in expression (8), i.e. the mean growth rate of firms adjusting employment against the trend of their regional industry. In addition, we examine whether regional industries tend to be smaller with a propensity of firms to grow into the same direction. Being located in a relatively small industry allows firms to share one labor market of skills with other industries. As our measure for the homogeneity of employment adjustment we take the average sector-congruent growth rate (CGR) which measures the extent to which all N firms in region r in sector s at time t adjust employment into the same direction as the regional industry.

$$CGR_{r,s,t} = \left| \frac{\sum_i SCA_{i,t}}{N} \right| \quad (10)$$

We use the total employment of a regional industry, as well as its employment share within a region, as alternative measures for the size of a regional industry \mathcal{S} , which we estimate as a function of average sector-congruent (CGR) and sector-adverse growth rates (AGR), including region, sector, and time fixed effects as controls.

$$S_{r,s,t} = \beta_1 CGR_{r,s,t} + \beta_2 AGR_{r,s,t} + \phi_r + \phi_s + \phi_t + \varepsilon_{i,t} \quad (11)$$

Results from estimating equation (11), which are contained in columns I and II in Table V, are consistent for both measure of regional industry size. In fact, we find the size of regional industries to increase with the intensity of average sector-adverse growth, indicating that large industries are shaped by a more intense exchange of highly qualified workers between firms. In general, increasing the intensity of adverse growth by one standard deviation, i.e. by four percent, is associated with a rise in the regional employment share of an industry by about one percent, as well as with a rise in total employment within a cluster by slightly above ten highly qualified workers. While these findings by their nature remain suggestive and have nothing to say about causality, they support the suspicion that patterns of industrial agglomeration emerge from firms reaping the gains from intra-industry change.

In what follows we wish to corroborate this idea by investigating whether a correlation exists between the regional concentration of industries and the dynamics of industrial change. We use the Ellison-Glaeser-Index (Ellison/Glaeser 1997) as our measure of industrial concentration. The Ellison-Glaeser-Index (EGI) measures the extent to which industry s is regionally concentrated at time t and is defined as

$$EGI_{s,t} = \frac{G_{s,t} - (1 - \sum_r (E_{r,t}/E_t))H_{s,t}}{(1 - \sum_r (E_{r,t}/E_t))(1 - H_{s,t})} \quad (12)$$

G represents the spatial Gini coefficient of industry s . It is constructed by taking the squared sum of the differences between relative national employment in region r and relative sectoral employment in region r across all regions. G equals zero if employment in sector s is distributed across regions in exactly the same way as overall employment, and takes on a value close to one if a sector is concentrated within one region.

$$G_{s,t} = \sum_r \left[\frac{E_{r,t}}{E_t} - \frac{E_{s,r,t}}{E_{s,t}} \right]^2 \quad (13)$$

Unfortunately, the Gini coefficient does not adequately differentiate between true sectoral clustering on the one hand, and the intensity to which employment is clustered due to differences in the size of firms and regions. By means of an example, if all employment within a sector is concentrated within one firm, it is not surprising to find sectoral employment to be concentrated within one region. This concentration is, however, due to employment being concentrated in a firm, and not to unique

sectoral agglomeration. The EGI corrects for regional size and employment clustering among firms by including relative region size and the Hirschman-Herfindahl index H of employment concentration between plants i within one sector into the index.

$$H_{s,t} = \sum_i z_{i,t}^2 \quad (14)$$

The EGI rises with the extent to which sectoral clustering deviates from a random distribution of sectors under a given distribution of firm and region sizes. Although inherently ad hoc, Ellison/Glaeser (1997) propose the following classification of sectors with respect to their concentration: a range between .2 and .5 for the sector-specific EGI indicates sectoral concentration, with an EGI exceeding .5 pointing to high sectoral concentration. Sectors with an EGI below .2 are regarded as not being concentrated at all, with negative values of the EGI indicating excess dispersion.

Graph VI contains the evolution of sectoral concentration in Western Germany. The two most striking observations emerging from the graph are the low degree of concentration of Western German industries on the one hand, and the relative stability of intra-sectoral concentration, which is in line with findings by Südekum (2006). Out of 18 industries only four qualify as being concentrated. Disregarding Agriculture/Fishing/Mining, which is by definition concentrated around natural resources, and Transportation, the concentration of which is to a large extent rooted in the nature of ports and airports as indivisible goods, only the Iron and Steel Industry and the Insurance and Banking Sector display a certain extent of concentration with the former moving towards more dispersion, and the latter towards increased concentration.

In order to test whether sectoral differences in the dynamics of industrial change contribute to differences in sectoral concentration we regress the EGI on the sectoral means of sector-congruent and sector-adverse shock intensity and include sector size, as well as time and sector specific fixed effects as further controls.

$$EGI_{s,t} = \varphi_1 CGR_{s,t} + \varphi_2 AGR_{s,t} + \varphi_3 Empl_{s,t} + \phi_t + \phi_s + \varepsilon_{s,t} \quad (15)$$

If the sectoral dynamics of labor market adjustments shaped the geography of industrial location, we should find industries characterized by larger sector-adverse growth to be more concentrated in order to reap the benefits from intra-industry churning. Conversely, with increasing sector-congruent adjustments firms should tend to disperse regionally so as to benefit from the exchange of jobs with other industries. With these considerations in mind we would interpret a significantly negative

coefficient φ_1 , and a significantly positive coefficient φ_2 , as evidence that the dynamics of firm growth within industries, i.e. the extent to which firms differ in their direction of growth and thereby churn jobs within industries, or to which they all grow in line with their industry, is correlated with the geography of industrial location.

Column III in Table V contains the results of estimating equation (15). In line with our expectations, φ_1 is significantly negative, implying that sectors with large sector-congruent employment adjustments are more dispersed. The coefficient is, however, rather small with an increase in average sector-congruent shocks by one standard deviation, i.e. by about five percent, reducing the EGI by .001. Findings are even weaker for average sector-adverse growth. While φ_1 shows the expected sign, it is smaller and not significant. Thus, while there is some indication for a correlation between the dynamics of intra-industry employment adjustment and the concentration of industries, the size of such effects is rather small.

Summing up, the results in Table V provide preliminary evidence on the interplay between sectoral adjustment and the geography of industries. In general, we find indication for the industry-specific dynamics of labor market adjustments to be correlated with regional industry size and overall sectoral concentration. The negligible size of this connection is, however, in line with the general insight that the distribution of industries across German regions is rather stable, i.e. there is inherently low change in the geography of industrial location. Finding the dynamics of skilled labor markets to be only of minor importance for the spatial distribution of industries emphasizes the multitude of factors affecting location decisions of firms, among which the benefits from human capital externalities play only a moderate role.

VI. Conclusion

Inspired by the literatures on industrial change and on social returns from human capital we examined the joint importance of human capital endowments and job turnover for regional prosperity. While the two literatures share the same object of study, i.e. the sources of regional productivity and growth, they have so far developed rather separately. Since we regard the complementarity of aggregate human capital and dynamic labor markets as the missing link between the two branches, we investigated whether productivity effects arise from the joint presence of aggregate education and high local intensities of job turnover. Three insights emerged.

First, we find strong evidence for the complementarity of aggregate human capital and industrial change. More specifically, while productivity enhancing regional change is more likely to occur in human capital rich regions, social returns to human capital necessitate dynamic labor markets to come about. In line with Südekum/Findeisen (2008), we find productivity effects from the joint presence of industrial change and aggregate education to be most pronounced in growing industries.

Secondly, our findings on the microeconomic level support the notion that human capital externalities come about through industrial change within local labor markets. Specifically, we found productivity in growing firms to rise with the local supply of highly qualified workers, indicating that firms expanding employment in dynamic and skilled regions benefit from efficient labor market matches, from knowledge embodied in workers changing firms, and from the mobility of workers between industries.

Thirdly, despite the joint importance of industrial change and local human capital for productivity effects to arise, we find only weak indication that industry-specific labor market dynamics shape the geography of industrial location. The negligible size of these effects emphasizes the persistence of regional industrial patterns, as well as the multitude of factors influencing the location decision of firms.

Two lessons arise from our findings for the design of regional policies. The first lesson is that in order to keep up with the demand to constantly reinvent themselves, regions and firms both rely on dynamic regional labor markets and on local human capital endowments. Any policy committed to enhancing long-term regional prospects is therefore well advised to bear in mind that a diversified and dynamic industry structure and a skilled workforce are equally important conditions for successful industrial change. Given the importance of labor market dynamics, fostering the development of a large number of small, innovative firms might be more beneficial than attracting a single large firm alone. This insight is very much in line with Saxenian (1994), who argues that the decisive reason for why the computer industry in Silicon Valley is more successful than in Boston's Route 128 region is its large number of small, innovative firms, which allows each firm to adjust more efficiently to industrial change than the small number of large corporations can in Boston. The second lesson is that this combination yields productivity effects predominantly in growing regional industries. In line with the literature on the life cycles of industries, in declining regions it might therefore be more promising to actively support the development of young, innovative industries which allow for regional reinvention, rather than to expect the combination of human capital and intense labor market turnover to bring about productivity enhancing industrial change.

Two questions remain for further research. First, given the importance of aggregate human capital for regional productivity, furthering our understanding of the microeconomic foundations through which human capital externalities arise is clearly desirable. So far, existing studies provide strong support for the notion that regional education facilitates the diffusion of technological knowledge. Insights into the relative importance of matching and sharing externalities have remained, in contrast, rather vague. Closely related to issue of how productivity growth in skilled regions comes about is the question of how aggregate education translates into improved opportunities for successful regional change. In this respect, understanding the role of human capital for innovation and the inter-sectoral transmission of knowledge, as well as for entrepreneurship and the dynamics of firm growth is clearly needed. Addressing these issues, the empirical literature inspired by Acs/Audretsch (1988) and Audretsch/Feldman (1996) provides a welcoming starting point in order to investigate the role of human capital, innovation, and entrepreneurship in growing and in declining industries, respectively.

References

- Acs, Zoltan J. and David B. Audretsch. 1988. Innovation in Large and Small Firms: An Empirical Analysis. *American Economic Review* 78: 678-90.
- Aghion, Philippe and Peter Howitt. 1992. A Model of Growth through Creative Destruction. *Econometrica* 60: 323-51.
- Almeida, Paul and Bruce Kogut. 1999. Localization of Knowledge and the Mobility of Engineers in Regional Networks. *Management Science* 45: 905-17.
- Audretsch, David B. and Maryann P. Feldman. 1996. R&D Spillovers and the Geography of Innovation and Production. *American Economic Review* 86: 630-40.
- Audretsch, David B. and Maryann P. Feldman. 2004. Knowledge Spillovers and the Geography of Innovation; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Baldwin, John, Timothy Dunne and John Haltiwanger. 1998. A Comparison of Job Creation and Job Destruction in Canada and the United States. *Review of Economics and Statistics* 80: 347-56.
- Bundesforschungsanstalt für Landeskunde und Raumordnung. 1996. Neuabgrenzung der Raumordnungsregionen. *Mitteilungen und Informationen der BfLR*: 4-5.
- Birch, David. 1987. *Job Creation in America: How Our Smallest Companies Put The Most People to Work*. New York: Macmillan, Free Press; London: Collier Macmillan.
- Blien, Uwe and Helge Sanner. 2006. Structural Change and Regional Employment Dynamics. *IAB Discussion Paper* 06/2006. Nuremberg.
- Boeri, Tito and Ulrich Cramer. 1992. Employment Growth, Incumbents and Entrants. *International Journal of Industrial Organization* 10: 545-65.
- Borjas, George J. 1987. Self-Selection and the Earnings of Immigrants. *American Economic Review* 77: 531-53.
- Chinitz, Benjamin. 1966. Appropriate Goals for Regional Economic Policy. *Urban Studies* 3: 1-7.
- Chiswick, Barry R. 2005. *The Economics of Immigration*. Cheltenham UK: Edward Elgar Publishing.
- Ciccone, Antonio and Giovanni Peri. 2006. Identifying Human-Capital Externalities: Theory with Applications. *Review of Economic Studies* 73: 381-412.
- Combes, Pierre-Philippe, Thierry Magnac and Jean-Marc Robin. 2004. The Dynamics of Local Employment Growth in France. *Journal of Urban Economics* 56: 217-43.
- Davies, Jim B. 2002. Empirical Evidence on Human Capital Externalities. *Working Paper* 2003-11, Department of Finance, Canada.
- Davis, Steven and John Haltiwanger. 1992. Gross Job Creation, Gross Job Destruction, and Employment Reallocation. *Quarterly Journal of Economics* 107: 819-63.
- Davis, Steven and John Haltiwanger. 1999. Gross Job Flows; in: Ashenfelter, Orley and David Card (eds.). *Handbook of Labor Economics*. Elsevier: New York.
- Davis, Steven, John Haltiwanger and Scott Schuh. 1996. *Job Creation and Destruction*. Cambridge, MA: MIT Press.
- Desmet, Klaus and Esteban Rossi-Hansberg. 2009. Spatial Growth and Industry Age. Forthcoming: *Journal of Economic Theory*.

- Duranton, Gilles. 2006. Human Capital Externalities in Cities: Identification and Policy Issues; in: Arnott, Richard and Daniel McMillen (eds.) *A Companion to Urban Economics*. Oxford: Blackwell Publishing Ltd.
- Duranton, Gilles. 2007. Urban Evolutions: The Fast, the Slow, and the Still. *American Economic Review* 97: 197-121.
- Duranton, Gilles. 2008. Spatial Economics; in: Durlauf, Steven N. and Lawrence E. Blume (eds.) *The New Palgrave Dictionary of Economics*, Second Edition. London: Palgrave Macmillan.
- Duranton, Gilles and Diego Puga. 2000. Diversity and Specialization in Cities: Why, Where and When Does it Matter? *Urban Studies* 37: 533-56.
- Duranton, Gilles and Diego Puga. 2001. Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products. *American Economic Review* 91: 1454-77.
- Duranton, Gilles and Diego Puga. 2004. Micro-foundations of Urban Agglomeration Economies; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Eckey, Hans-Friedrich, Reinhold Kosfeld and Matthias Türck. 2006. Abgrenzung deutscher Arbeitsmarktregionen. *Raumforschung und Raumordnung* 64: 299-309.
- Ellison, Glenn and Edward L. Glaeser. 1997. Geographic Concentration in US Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy* 105: 889-927.
- Ellison, Glenn, Edward L. Glaeser and William Kerr. 2007. What Causes Industry Agglomeration? – Evidence from Coagglomeration Patterns. *NBER Working Paper* 13068.
- Faberman, Jason R. 2002. Job Flows and Labor Dynamics in the U.S. Rust Belt. Bureau of Labor Statistics, Washington. *Monthly Labor Review* September 2002: 3-10.
- Faberman, Jason R. 2007. The Relationship between the Establishment Age Distribution and Urban Growth. *Federal Reserve Bank of Philadelphia Working Paper*.
- Findeisen, Sebastian and Jens Südekum. 2008. Industry Churning and the Evolution of Industries. *Journal of Urban Economics* 64: 326-39.
- Fritsch, Michael and Udo Brix. 2004. The Establishment File of the German Social Insurance Statistics. *Schmollers Jahrbuch* 124: 184-90.
- Fu, Shihe. 2007. Smart Café Cities: Testing Human Capital Externalities in the Boston Metropolitan Area. *Journal of Urban Economics* 61: 86-111.
- Glaeser, Edward L. 2005. Reinventing Boston: 1630-2003. *Journal of Economic Geography* 5: 119-53.
- Glaeser, Edward L., Hedi D. Kallal, Jose A. Scheinkman and Andrei Shleifer. 1992. Growth in Cities. *The Journal of Political Economy* 100: 1126-52.
- Glaeser, Edward L. and Albert Saiz. 2003. The Rise of the Skilled City. *Brookings-Warton Papers on Urban Affairs* 5: 47-94.
- Glaeser, Edward L. and Jesse M. Shapiro. 2003. Urban Growth in the 1990s: Is City Living Back? *Journal of Regional Science* 43: 139-65.
- Green, Francis, Stephen Machin and Alan Manning. 1996. The Employer-Size Wage Effect: Can Dynamic Monopsony Provide an Explanation? *Oxford Economic Papers* 48: 433-55.

- Grossetti, Michael. 2007. Are French Networks Different? *Social Networks* 29: 391-404.
- Helsley, Robert W. and William C. Strange. 1990. Matching and Agglomeration Economies in a System of Cities. *Regional Science and Urban Economics* 20: 189-212.
- Henderson, Vernon, Ari Kuncuro and Matt Turner. 1995. Industrial Development in Cities. *The Journal of Political Economy* 103: 1067-90.
- Heuermann, Daniel F. 2008. Human Capital Externalities in Western Germany. *IAAEG Discussion Paper* 05/2008. University of Trier.
- Heuermann, Daniel F. 2009. Career Networks and Matching Externalities – Evidence on the Microeconomic Foundations of Human Capital Externalities. *IAAEG Discussion Paper* 01/2009. University of Trier.
- Holmes, Thomas J. and John J. Stevens. 2002. Geographic Concentration and Establishment Scale. *The Review of Economic and Statistics* 84: 682-90.
- Jacobs, Jane. 1969. *The Economy of Cities*. New York: Random House.
- Jovanovic, Boyan. 1982. Selection and the Evolution of Industry. *Econometrica* 50: 649-70.
- Jovanovic, Boyan and Yaw Nyarko. 1995. The Transfer of Human Capital. *Journal of Economic Dynamics and Control* 19: 1033-64.
- Kirby, Simon and Rebecca Riley. 2008. The External Returns to Education - UK Evidence Using Repeated Cross-Sections. *Labour Economics* 15: 619-30.
- Kolko, Jed. 2008. Urbanization, Agglomeration, and Co-Agglomeration of Service Industries. Forthcoming: *NBER Conference Volume on Agglomeration*.
- Krueger, Alan B. and Mikael Lindahl. 1999. Education for Growth in Sweden and the World. *Swedish Economic Policy Review* 6: 289-339.
- Krugman, Paul. 1991. *Geography and Trade*. Cambridge, MA: MIT Press.
- Lucas, Robert E. 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* 22: 3-42.
- Moretti, Enrico. 2000. Do Wages Compensate for Risk of Unemployment? Parametric and Semiparametric Evidence from Seasonal Jobs. *Journal of Risk and Uncertainty* 20: 45-66.
- Moretti, Enrico. 2004a. Human Capital Externalities in Cities; in: Henderson, James V. and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Elsevier: San Diego, Oxford, London.
- Moretti, Enrico. 2004b. Estimation the social return to higher education: evidence from longitudinal and repeated cross-sectional data. *Journal of Econometrics* 121: 175-212.
- Moretti, Enrico. 2008. Real Wage Inequality. *NBER Working Paper* 14370.
- Nelson, Richard R. and Edmund S. Phelps. 1966. Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review* 56: 69-75.
- Overman, Henry G. and Diego Puga. 2008. Labour Pooling as a Source of Agglomeration: An Empirical Investigation. *Working Paper 2008-05*. IMDEA, University of Madrid.
- Rosenthal, Stuart S. and William C. Strange. 2001. The Determinants of Agglomeration. *Journal of Urban Economics* 50: 191-229.

- Rosenthal, Stuart S. and William C. Strange. 2004. Evidence on the Nature and Sources of Agglomeration Economies; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Urban and Regional Economics*. Amsterdam: Elsevier-North Holland.
- Rosenthal, Stuart S. and William C. Strange. 2008. The Attenuation of Human Capital Spillovers. *Journal of Urban Economics* 64: 373-89.
- Santarelli, Enrico and Macro Vivarelli. 2007. Entrepreneurship and the Process of Firms' Entry, Survival and Growth. *Industrial and Corporate Change* 16: 455-88.
- Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Schultz, Theodore W. 1963. *The Economic Value of Education*. New York, London: Columbia University Press.
- Shapiro, Jesse M. 2006. Smart Cities: Explaining the Relationship between City Growth and Human Capital. *The Review of Economics and Statistics* 88: 389-432.
- Simon, Curtis J. 1998. Human Capital and Metropolitan Employment Growth. *Journal of Urban Economics* 43: 223 – 43.
- Simon, Curtis J. 2004. Industrial Reallocation across US Cities, 1977-1997. *Journal of Urban Economics* 56: 119-43.
- Simon, Curtis, J. and Clark Nardinelli. 2002. Human Capital and the Rise of American Cities, 1900-1990. *Regional Science and Urban Economics* 32: 59-96.
- Spengler, Anja. 2007. The Establishment History Panel. *FDZ Methodenreport*. Institute for Labor and Employment Research, Nuremberg.
- Stahl, Konrad and Uwe Walz. 2001. Will There Be a Concentration of Alikes? The Impact of Labor Market Structure on Industry Mix in the Presence of Product Market Shocks. *HWWA Discussion Paper* 140. Hamburg.
- Südekum, Jens. 2006. Concentration and Specialization Trends in Germany since Re-Unification. *Regional Studies* 40: 861-73.
- von Thünen, Johann Heinrich. 1826. *Der isolirte Staat in Beziehung auf Landwirthschaft und Nationalökonomie, oder Untersuchungen über den Einfluß, den die Getreidepreise, der Reichthum des Bodens und die Abgaben auf den Ackerbau ausüben*. Hamburg: Perthes.
- Weber, Alfred. 1909. *Reine Theorie des Standortes*. Tübingen: Mohr.
- Welch, Finis. 1970. Education in Production. *Journal of Political Economy* 78: 35-59.
- Yankow, Jeffrey J. 2006. Why Do Cities Pay More? An Empirical Examination of Some Competing Theories of the Urban Wage Premium. *Journal of Urban Economics* 60: 139-61.

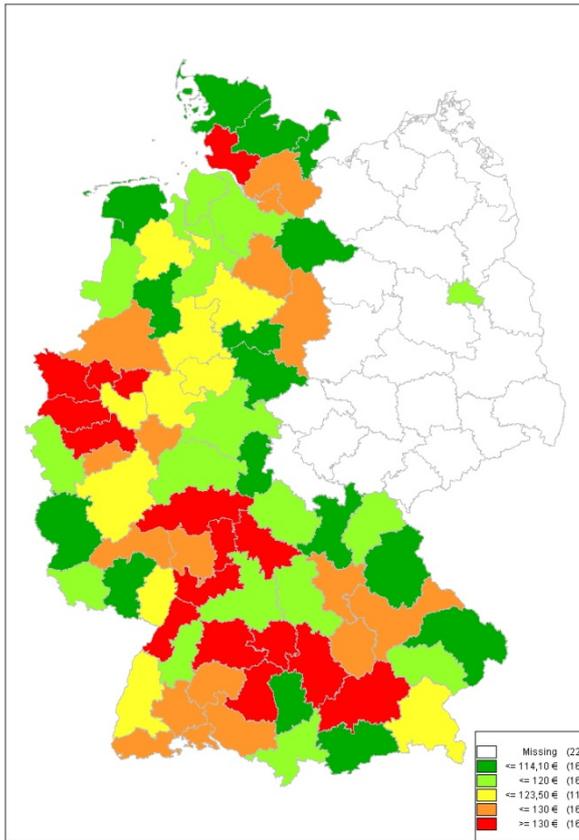
Appendix

Table I – Industry Classification and Employment Characteristics

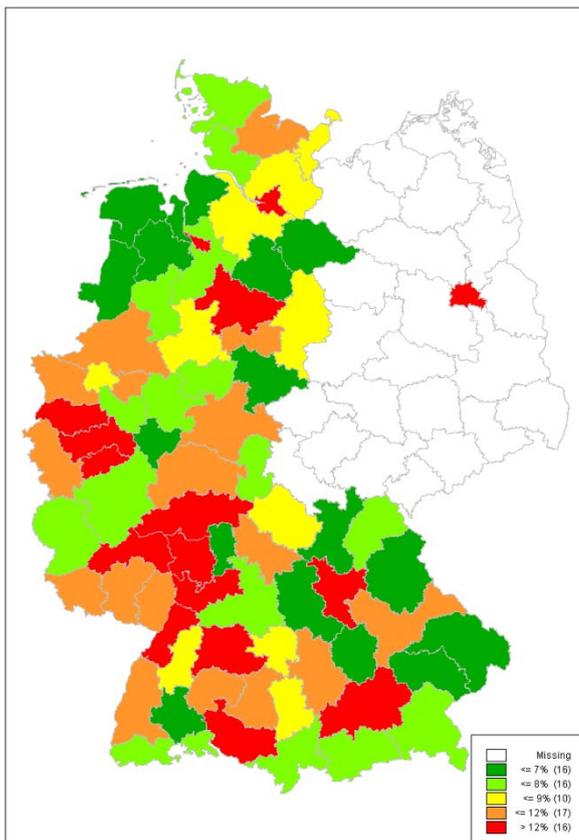
	Average Wages of Highly Qualified Workers	Employment of Highly Qualified Workers
Chemical Industry	121.79	87,912
Insurance and Banking	119.46	81,000
Mechanical Engineering	117.02	162,813
Iron and Steel Industry	116.87	17,022
Electrical Engineering	116.48	167,236
Food Production and Processing	105.66	11,952
Public Sector	103.42	160,236
Construction	102.91	32,872
Education	101.80	121,714
Furniture and Textiles	101.70	22,130
Real Estate	101.40	146,263
Agriculture, Fishing, Mining	100.47	32,526
Media, Art, Photography	97.68	42,528
Retail	97.36	99,395
Transportation	96.44	24,583
Legal and Economic Consulting	95.64	109,802
Hotels and Catering	91.10	19,395
Consumer Services	90.66	26,415
Weighted Average/Sum	106.70	1,365,794

Notes: Employment of Highly Qualified Workers covers all employees holding a degree from a university or a technical college, who are subject to social security contributions. This definition excludes self-employed and public servants. Average Wages of Highly Qualified Workers are defined as average daily gross wages in 2000.

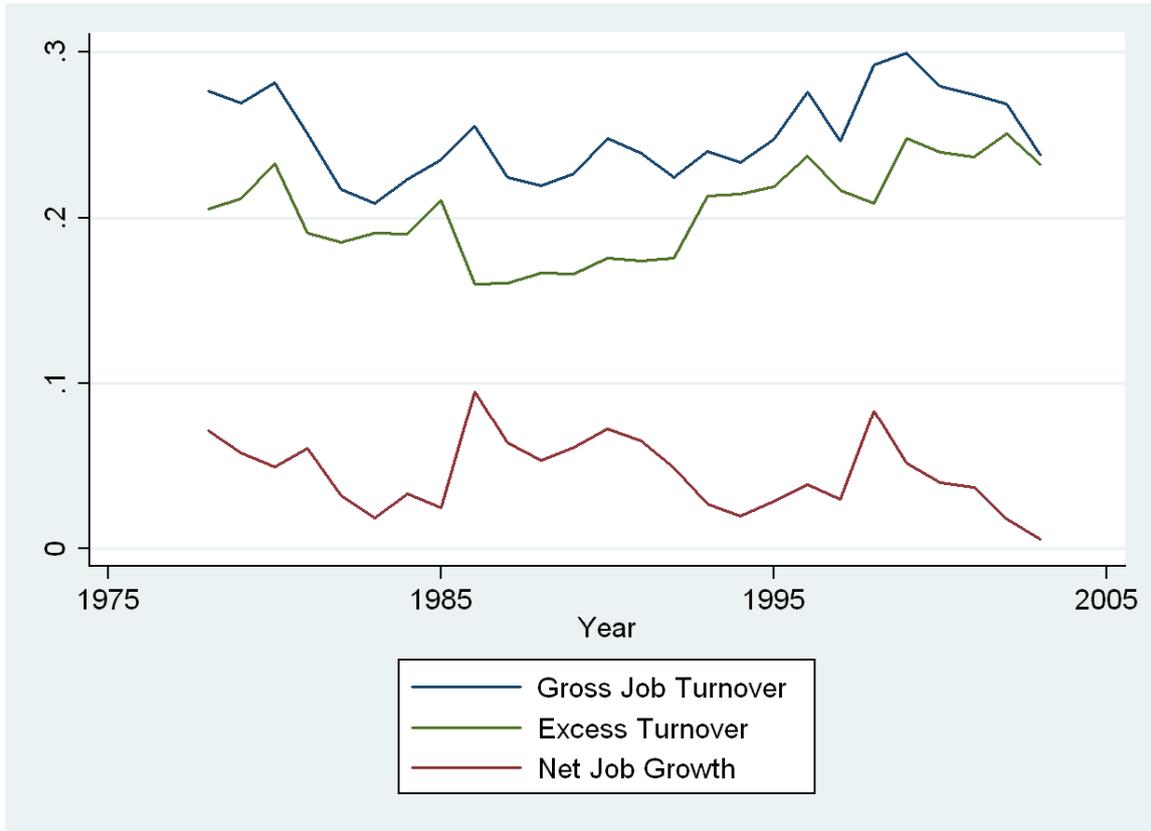
Map I: Regional Average Wages of Highly Qualified Workers, 2001



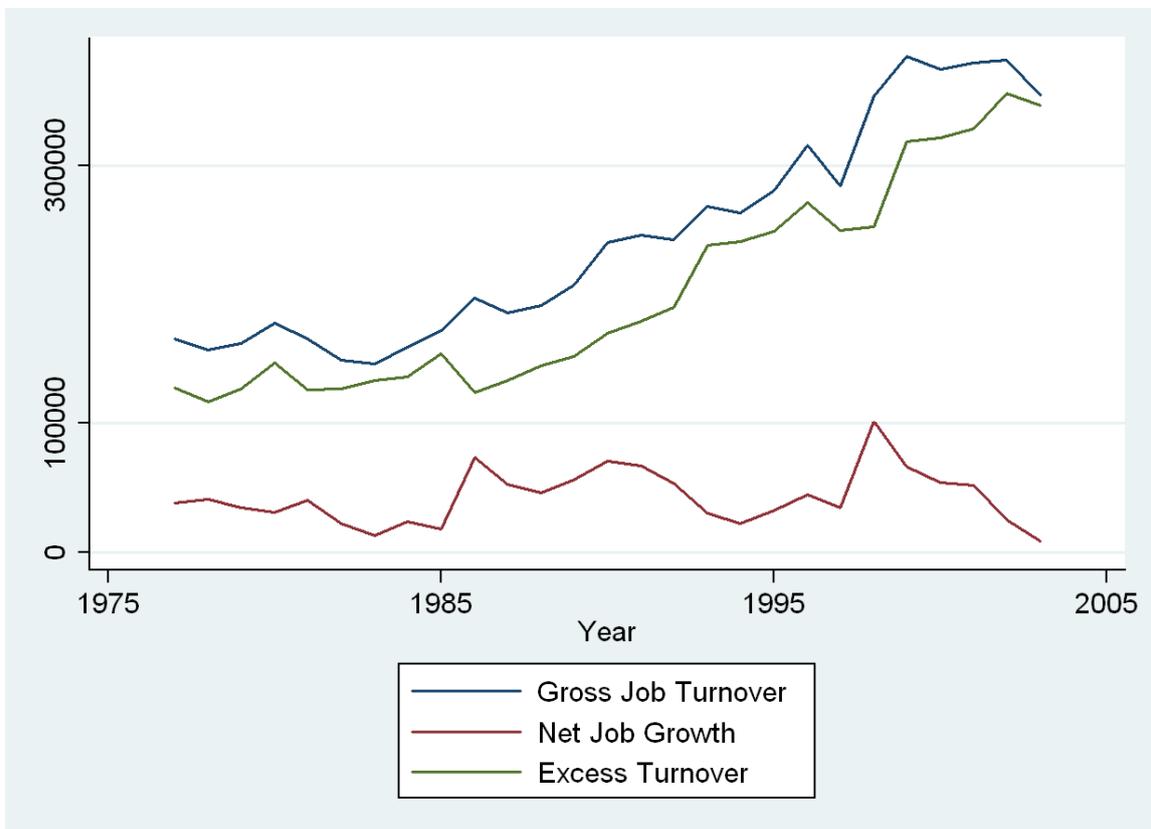
Map II: Regional Share of Highly Qualified Workers, 2001



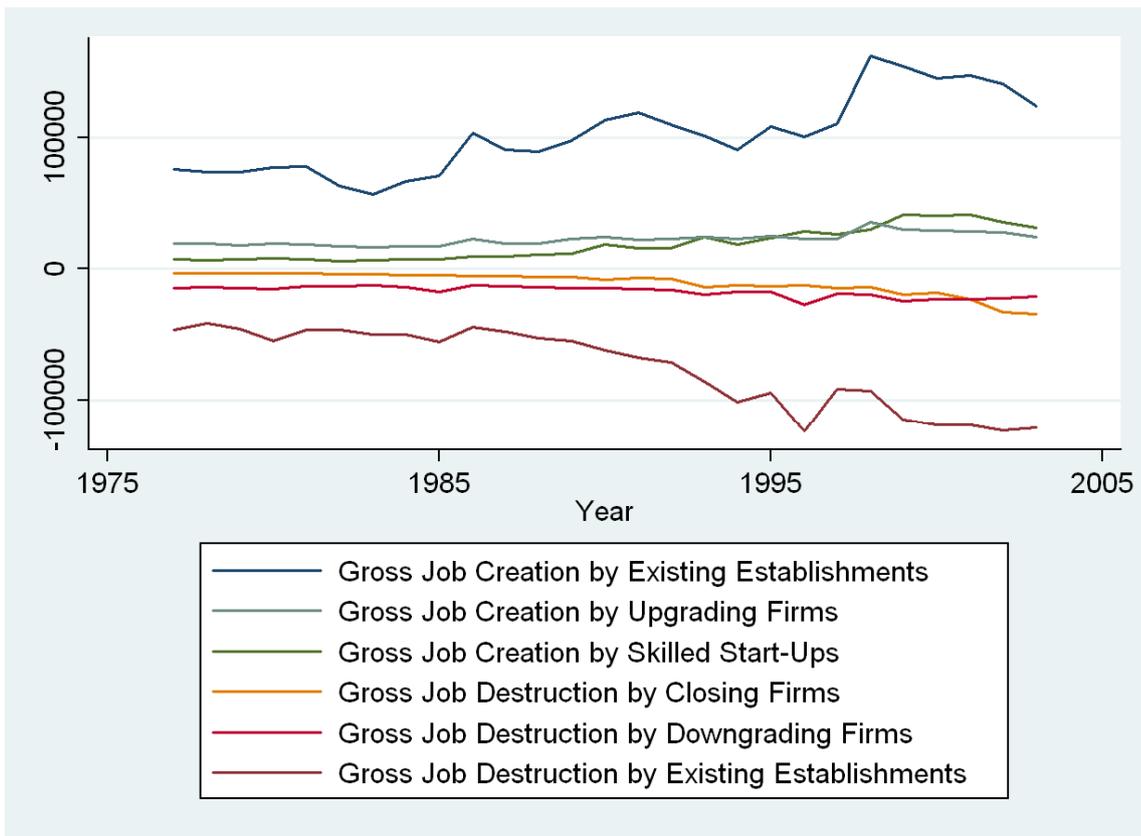
Graph I – Gross Turnover, Excess Turnover and Net Job Change: Rates



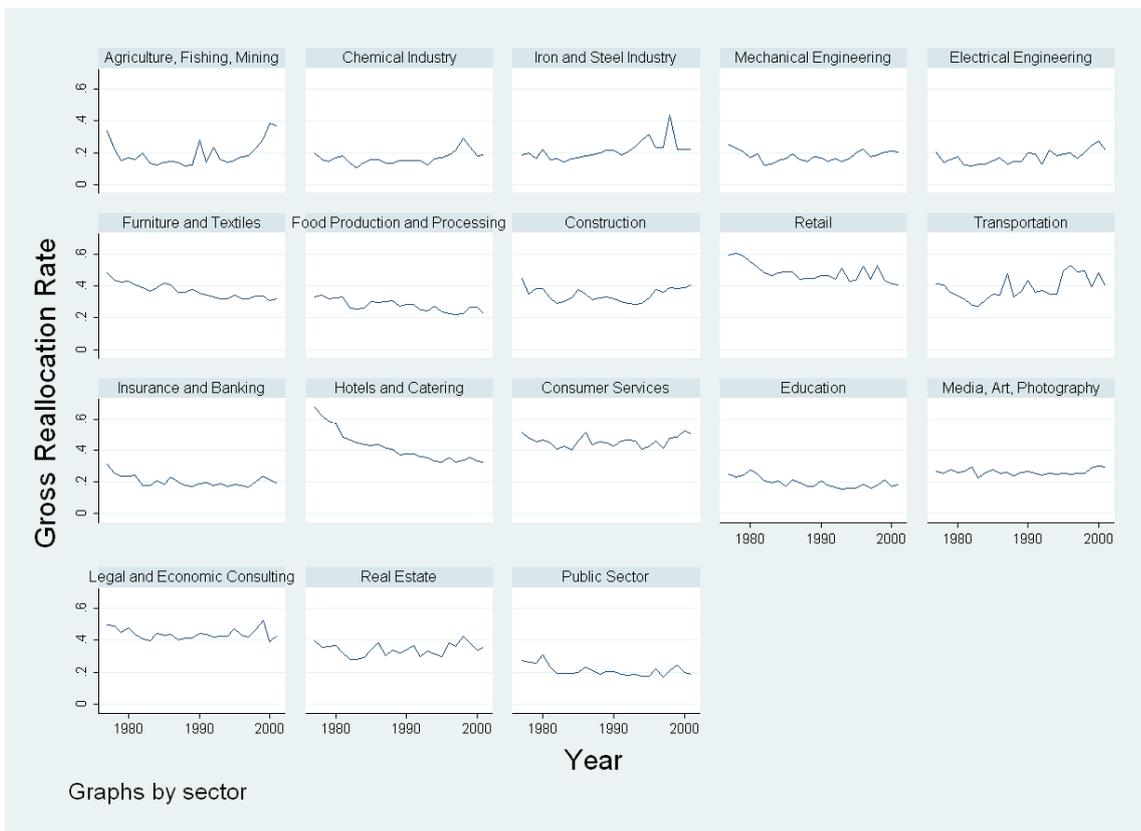
Graph II – Gross Turnover, Excess Turnover and Net Job Change: Flows



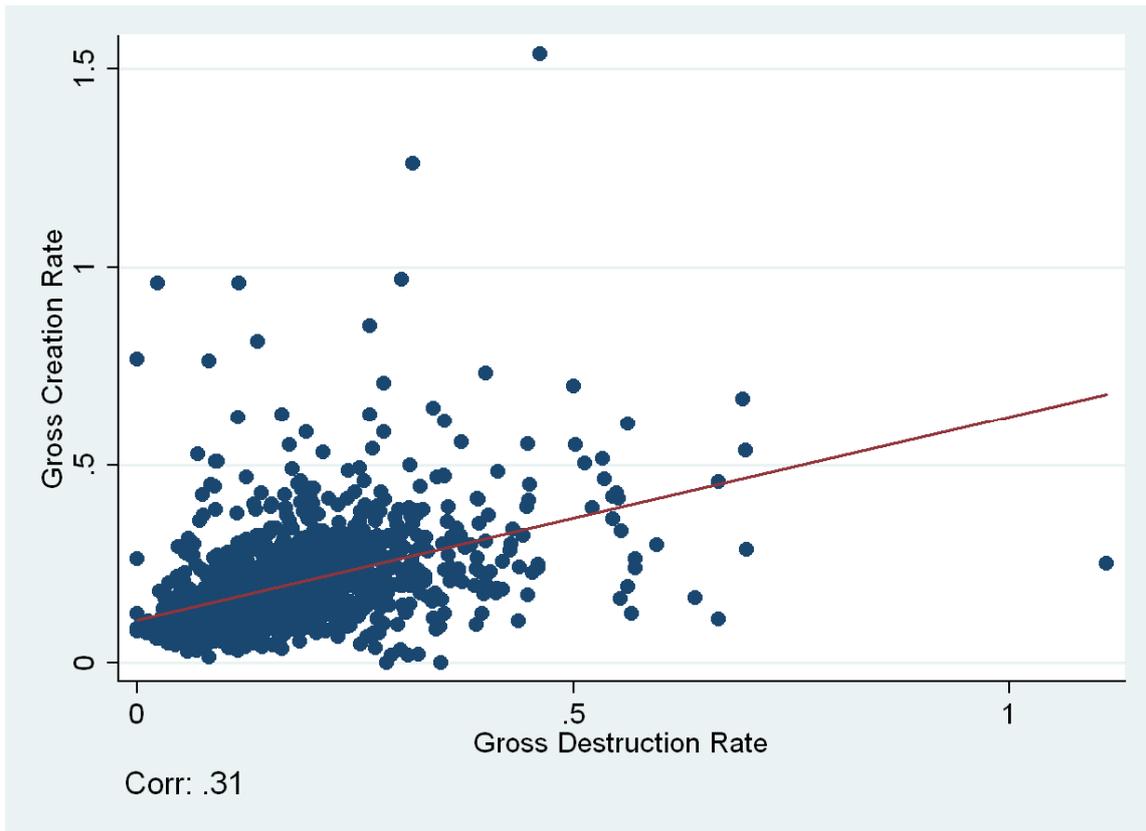
Graph III – Job Creation and Destruction by Firm Type: Flows



Graph IV – Sectoral Gross Reallocation Rates



Graph V – Annual Gross Creation and Destruction Rates, Region-Sectoral Level, 2002



Graph VI – Industrial Concentration by Sector

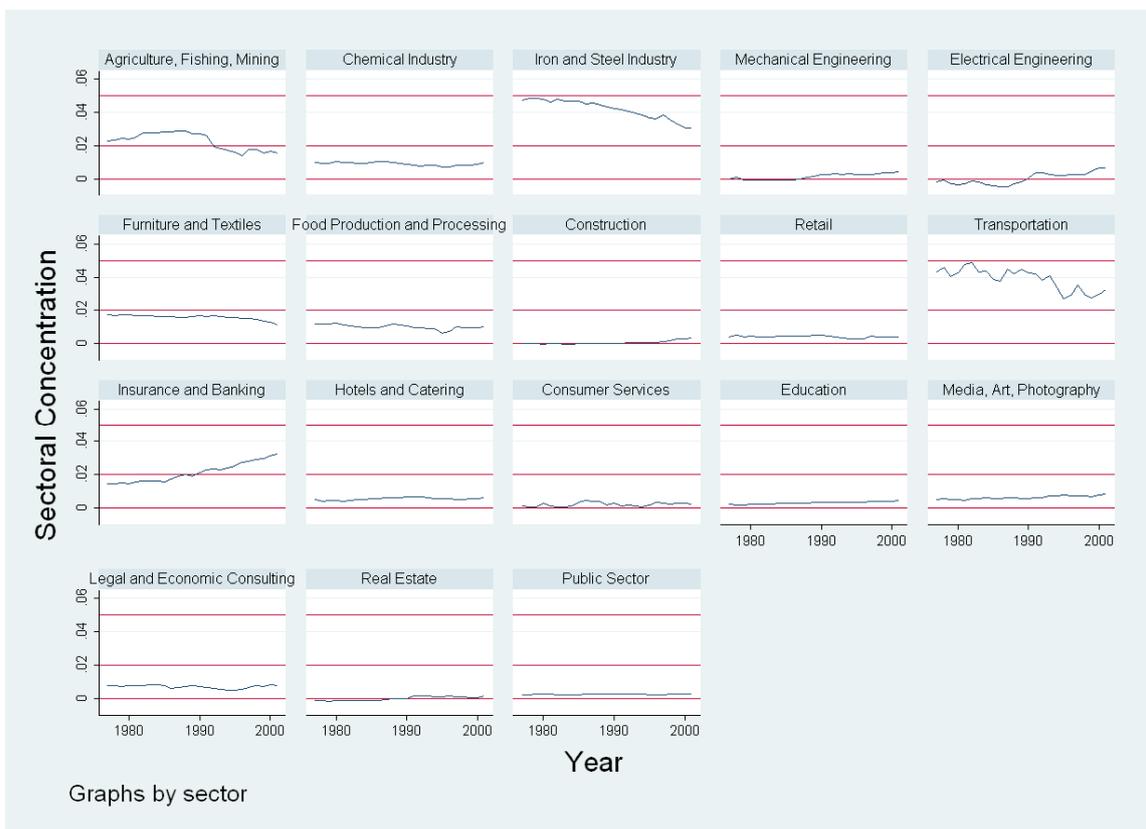


Table II – Skills and Industrial Change: Regional Industries (I)

	Dependent Variable:	ln(Mean Wage of Highly Qualified Workers per Region [per Sector] per Year)				
		(I)	(II)	(III)	(IV)	(V)
Change	Region-Sectoral Job Turnover Rate	-	-1.41 (.008)***	-1.88 (.014)***	-.523 (.032)***	-
	Region-Sectoral Job Turnover Rate ²	-		-	.256 (.019)***	-
	Regional Job Turnover Rate	-		-	-	-.466 (.084)***
Skills	Region-Sectoral Share HQ	-1.17 (.066)***	-1.42 (.072)***	-1.36 (.074)***	-1.57 (.087)***	-
	Region-Sectoral Share HQ ²	1.93 (.135)***	2.09 (.135)***	2.05 (.136)***	2.31 (.150)***	-
	Regional Share HQ	.139 (.468)	-	-.015 (.527)	-.432 (.535)***	-1.17 (.861)
	Regional Share HQ ²	-2.90 (1.37)**	-	-3.62 (1.43)**	-2.61 (1.45)*	-8.99 (2.28)***
Skills and Change	Region-Sectoral Share HQ*Region-Sectoral Job Turnover Rate	-	.699 (.089)***	.572 (.096)***	1.21 (.207)***	-
	(Region-Sectoral Share HQ*Region-Sectoral Job Turnover Rate) ²	-	-	-	-1.76 (.799)**	-
	Regional Share HQ*Region-Sectoral Job Turnover Rate	-	-	.924 (.225)***	2.61 (.489)***	-
	(Regional Share HQ*Region-Sectoral Job Turnover Rate) ²	-	-	-	-11.3 (3.31)***	-
	Regional Share HQ*Regional Job Turnover Rate	-	-	-	-	4.27 (1.13)***
Controls	Average Firm Size	.035 (.0004)***	.035 (.0004)***	.035 (.0004)***	.035 (.0004)***	-.016 (.018)
	Ln(No of HQ Workers per Region)	.441 (.041)	.541 (.033)***	.408 (.043)***	.395 (.043)***	.709 (.068)***
	Ln(No of HQ Workers per Region) ²	-.025 (.003)***	-.031 (.002)***	.037 (.003)***	-.022 (.003)***	-.015 (.005)***
	Ln(No of HQ Workers per Region-Sector)	.056 (.003)***	.038 (.003)***	-.023 (.003)***	.039 (.003)***	-
	Ln(No of HQ Workers per Region-Sector) ²	.002 (.0003)***	.003 (.0003)***	.003 (.0003)***	.002 (.0003)***	-
	Regional Unemployment Rate	-	.0002 (.001)	-.0008 (.001)	-.0008 (.001)	-.008 (.002)***
	Regional Unemployment Rate*Job Turnover Rate	-	.003 (.015)	.019 (.018)	.022 (.017)	.143 (.027)***
	Year Dummies	Yes	Yes	Yes	Yes	Yes
	Sector Dummies	Yes	Yes	Yes	Yes	No
	Region Dummies	Yes	Yes	Yes	Yes	Yes
Adj. R ²	.70	.71	.71	.71	.94	
No. of Observations	33,382	31,950	31,950	31,950	1,776	

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; all columns refer to sectors within regions as their unit of observation, except Column III, where the labor market region is the unit of observation; consistently, Average Firm Size is measured on region-sectoral level, except in Column III, where it refers to regional averages.

Table III – Skills and Industrial Change: Regional Industries (II)

Dependent Variable:	ln(Mean Wage of Highly Qualified Workers per Region per Sector per Year)				
	(I)	(II)	(III)	(IV)	(V)
Change Intensity	-.216 (.019)***	-.121 (.024)***	-.305 (.033)***	-.117 (.024)***	-.026 (.044)
Region-Sectoral Share HQ *Change Intensity	.680 (.127)***	.375 (.163)**	.702 (.221)***	.599 (.151)***	.042 (.326)
Regional Share HQ *Change Intensity	1.07 (.322)***	.813 (.395)**	1.34 (.529)***	.915 (.407)**	.822 (.803)
Indicator for Intensity of Industrial Change	Job Creation Rate	Job Destruction Rate	Excess Churning Rate	Positive Job Growth Rate	Negative Job Growth Rate
Adj. R ²	.71	.70	.70	.71	.66
No. of Observations	31,950	33,282	33,282	23,842	9,372

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; control variables throughout all regressions are Regional Share of HQ, Region-Sectoral Share of HQ, Region Size, Region-Sectoral Size, as well as their respective squares, and Average Region-Sectoral Firm Size, Unemployment, and an interaction term containing the product of Unemployment and the Labor Market Shock; all regressions contain full sets of region, sector, and time dummies.

Table IV – Adverse Employment Adjustment and Human Capital Externalities: Firms

		Dependent Variable:	ln(Median Wage of Highly Qualified Workers per Firm per Year)				
			(I)	(II)	(III)	(IV)	(V)
Adverse Change	Firm	Sector-Congruent Firm Adjustment *	.093 (.007)***	.091 (.007)***	-.007 (.032)	.099 (.007)***	.057 (.019)***
		Average Adverse Growth					
Adverse Change	Sector	Sector-Adverse Firm Adjustment *	.023 (.005)***	.020 (.006)***	.012 (.012)	.004 (.011)	.020 (.008)***
		Sector Growth					
Industrial Change	Firm	Sector-Congruent Firm Adjustment	-.041 (.001)***	-.040 (.001)***	-.022 (.005)***	-.042 (.001)***	-.031 (.003)***
		Sector-Adverse Firm Adjustment	-.026 (.001)***	-.028 (.001)***	-.017 (.001)***	-.015 (.001)***	-.032 (.001)***
	Reg-Sect	Sector Growth	-.002 (.009)	-.009 (.003)***	-.014 (.004)***	-.009 (.003)***	-.009 (.007)
		Average Adverse Adjustment	-.129 (.015)***	-.058 (.006)***	-.042 (.006)***	-.076 (.007)***	-.031 (.009)***
Controls	Share of HQ Employees		-.317 (.011)***	-.315 (.012)***	-.325 (.015)***	-.319 (.012)***	-.272 (.025)***
	Share of HQ Employees ²		.402 (.024)***	.399 (.027)***	.403 (.034)***	.406 (.028)***	.343 (.059)***
	Share of HQ Employees ³		-.227 (.016)***	-.224 (.017)***	-.225 (.021)***	-.229 (.018)***	-.198 (.038)***
	Number of Employees		17.7 (.279)***	16.5 (.378)***	19.0 (.423)***	17.2 (.338)***	18.2 (.574)***
	Number of Employees ²		-49.2 (2.08)***	-45.0 (2.73)***	58.2 (3.43)***	-46.6 (2.47)***	-53.5 (4.44)***
	Number of Employees ³		.003 (.0003)***	.004 (.0004)***	.006 (.0006)***	.004 (.0003)***	.006 (.0007)***
	Year Dummies		Yes	Yes	Yes	Yes	Yes
	Sector Dummies		Yes	Yes	Yes	Yes	Yes
	Region Dummies		Yes	Yes	Yes	Yes	Yes
	Firm Fixed Effects		Yes	Yes	Yes	Yes	Yes
Sample		All Firms	Growing Firms	Shrinking Firms	Growing Sectors	Contracting Sectors	
Adj. R ²		.10	.09	.07	.09	.07	
No. of Observations		3,272,125	2,833,135	2,146,351	2,526,205	784,889	

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors for Number of Employees are multiplied by 10⁵, coefficients and standard errors for quadratic and cubic terms thereof are multiplied by 10¹⁰.

Table V – The Dynamics of Industry Change and the Geography of Industrial Location

Dependent Variable:	Relative Region-Sectoral Employment	Ln(Absolute Region-Sectoral Employment)	Ellison-Glaeser Index of Industrial Concentration
	(I)	(II)	(III)
Average Sector-Congruent Adjustment, Sectoral Level	-	-	-.025 (.009)***
Average Sector-Adverse Adjustment, Sectoral Level	-	-	.009 (.02)
Average Sector-Congruent Adjustment, Region-Sectoral Level	-.012 (.008)	-.006 (.008)	-
Average Sector-Adverse Adjustment, Region-Sectoral Level	.023 (.009)***	.029 (.009)***	-
Sectoral Employment	-	-	.113 (.011)***
Year Dummies	Yes	Yes	Yes
Sector Dummies	Yes	Yes	Yes
Region Dummies	Yes	Yes	No
Adj. R ²	.14	.81	.95
No. of Observations	31,950	31,950	450

Notes: Standard errors in parentheses; ***, **, and * indicate significance at the 1% level, the 5% level, and the 10% level respectively; coefficients for constants are not reported here; coefficients and standard errors for sectoral employment are multiplied by 10⁶.

Conclusion: Human Capital Externalities and Regional Policy

In this final chapter of the dissertation we examine the implications arising from our results for the design of German and European regional policies. After briefly summarizing the core results from our research, we discuss the potential of public investments into education and into infrastructure to increase overall social returns to human capital, and to promote regional wage equality. Finally, we extend our policy recommendations from the German case to the level of the European Union.

The four papers of this dissertation provide a coherent picture of the scope of human capital externalities as an explanation for regional wage differentials, as well as of the microeconomic mechanisms through which external productivity effects from regional human capital endowments arise. Our results indicate that aggregate education has a significantly positive impact on wages of highly and, to a lesser extent, of non-highly qualified workers across regions in Western Germany. The microeconomic mechanisms through which social returns to human capital come about are more complex than previously thought. Thus, productivity effects from aggregate levels of education are not only caused by spillovers of technological knowledge, as frequently assumed in the literature, but also arise through improved job matching efficiency in skilled regions. We relate these effects to a more effective diffusion of information on career opportunities within social networks. Inspired by the insight that productivity effects from improved matching opportunities predominantly arise on occasions of job change, we finally investigate the importance of dynamic labor markets for human capital externalities to emerge. In contrast to previous research which has treated human capital externalities largely as a static concept, we show that productivity effects from human capital externalities increase with the intensity of regional job turnover. Specifically, we find productivity effects to accrue first and foremost to growing firms, which benefit from access to a large regional supply of skilled labor.

Our results indicate that human capital externalities exhibit two defining properties which are of importance for the design of regional policies. First, productivity enhancing effects from aggregate education are first and foremost rooted in the regional share of highly qualified workers. Second, external effects from aggregate education are of a localized nature, i.e. they occur predominantly within regional labor markets. Public policies might therefore enhance beneficial effects from human capital externalities by increasing the share of highly qualified workers within local workforces, or by enlarging the spatial scale of regional labor markets. Accordingly, in the next subsections we discuss the scope of educational and infrastructure policies to increase overall social returns to education, and to promote regional equality.

1. The Design of Regional Policies: Education

With the existence of social returns to human capital, individuals are likely to underinvest into their education since they are not compensated for productivity or amenity effects incurred by others. Addressing this source of inefficiency, primary and secondary education is not only provided for free in all industrialized countries, but school attendance is even made compulsory up to a certain age. Things are different with tertiary education, though, which is in most countries subject to tuition fees. However, our own results as well as arguments by Krueger/Lindahl (1999) and Moretti (2004) suggest that productivity enhancing human capital externalities are predominantly rooted in aggregate levels of university education, rather than in the stock of workers with primary and secondary education. Promoting academic qualifications therefore seems to be a viable option for policies committed to maximizing external productivity enhancing returns to education. We are well aware of the large number of arguments that can be advanced for prioritizing primary and secondary schooling over university education, with the occurrence of non-market externalities such as reduced crime rates or improved health related behavior being prime examples. Without going into debates on priorities here, we wish to draw attention to external productivity effects from human capital as an underestimated dimension in debates on the provision of higher education. In fact, our own results as well as findings obtained in a large literature on human capital externalities suggest that wage gains from social returns to tertiary education are likely to be substantial.

The crucial question for regional policies with respect to the provision of tertiary education concerns the spatial distribution of public investments into universities and research institutions. Political paradigms on the issue are changing at present. In general, regional policies have for decades furthered the provision of tertiary education first and foremost in peripheral regions with the objective of promoting regional convergence in education and wages. Nowadays, arguments are increasingly advanced for public investments to promote regional research clusters so as to maximize productivity effects from knowledge exchange between research institutions, universities, and firms. We discuss both approaches in turn.

Article 91 of the Constitution obliges the German government to implement measures for promoting equal standards of living across German regions (see Tetsch 1994). Consequently, furthering regional equality by decentralizing higher education has been a core element of regional structural policy in Germany since the 1960s (OECD 2007). Committed to the objective of increasing productivity in peripheral regions, national and regional governments have established universities and technical colleges in low skilled regions in order to attain convergence of regional educational structures

over time. While appealing at first sight, it is only today that the pitfalls of these policies become evident. In fact, the provision of higher education in peripheral regions might aggravate structural problems rather than promoting regional convergence. The underlying reason for such countervailing effects is that individual mobility increases with education. Thus, establishing a university in a peripheral region might leave regions with less skilled workers than before because the provision of tertiary education might make precisely the most able workers more mobile and thereby induce them to leave the region (Südekum 2005). Bound et al. (2004) provide empirical evidence for this notion by showing that the stock of college graduates working in a US state is weakly, if at all, related to the number of students graduating from college within this state. Hence, an exclusive reliance on educational infrastructure without adequate considerations of the dynamics of labor mobility and the regional demand for highly qualified workers is likely to impede rather than promote regional equality.

While promoting regional equality has lost prominence as an objective of education policy, improving the quality of research as well as encouraging cooperation between universities, research institutions, and firms has gradually moved to the focus of attention. This shift in priorities has brought about a reallocating of financial resources from the periphery to existing research and technology clusters, which are often located in skilled regions like Munich, Aachen, or Karlsruhe. In effect, such policies indirectly further the agglomeration of highly qualified workers in already skilled regions. Whether or not such policies enhance overall social returns to education hinges on the existence of non-linearities in productivity effects from aggregate education. Thus, furthering the agglomeration of highly qualified workers in skilled regions increases overall social returns to education only if productivity effects from human capital externalities are larger in skilled regions in absolute and in relative terms, i.e. if they increase at the margin.¹ Our results provide only weak evidence for such non-linearities. Specifically, in Paper II and III we find marginal social returns from aggregate human capital to be constant, while in Paper IV they even turn out to be slightly decreasing. In general, with the relative size of human capital externalities being the same across all regions, relocating the supply of tertiary education to skilled regions is unlikely to alter the overall sum of external productivity effects from aggregate education (Glaeser/Gottlieb 2008).

Summing up, public investments into academic qualifications are a promising way of increasing the overall sum of productivity enhancing external effects from human

¹ The reverse holds true for policy measures committed to a deconcentration of highly qualified workers, i.e. redirecting educated workers to peripheral regions yields productivity enhancing effects only with decreasing marginal social returns to human capital.

capital. In general, while the spatial distribution of universities and research institutions is likely to influence the overall sum of social returns only to a minor extent, it might have a substantial impact on the spatial distribution of wages and, hence, on the extent to which regional wage equality is attainable. As we shall discuss in more detail below, policies committed to increase wages and productivity in peripheral regions are well advised to complement investments into higher education by measure to promote the regional demand for highly qualified labor, so as to enable low-skilled regions to reap local productivity gains from human capital externalities.

2. The Design of Regional Policies: Regional Integration

In addition to increasing the supply of highly qualified workers, regional policies might enhance social returns to education by making local stocks of tacit knowledge accessible to a larger number of workers. Since tacit knowledge exhibits the properties of a local public good, connecting peripheral regions to skilled labor markets is likely to increase overall social returns to aggregate human capital, while at the same time causing wages and productivity to converge between regions. Regional policy can contribute to such an integration of neighboring labor markets by providing a system of public transport which effectively allows workers to commute between regions.

In order to get an impression of the extent to which human capital externalities percolate between regions, we compare the present distribution of regional average wages in Western Germany to the distribution that would prevail if regional human capital had no influence on intra-regional wages. Map I shows that average regional wages of highly qualified workers display a pronounced spatial autocorrelation, i.e. regions with above average wages are likely to be located close to other high-wage regions. As far as external productivity effects from human capital are concerned, the spatial autocorrelation of wages can either be driven by an underlying autocorrelation of regional shares of highly qualified workers, or by human capital externalities diffusing from skilled labor markets into adjacent regions. Excluding intra-regional human capital externalities allows us to see whether peripheral regions gain in the size of average wages relative to skilled regions, which we take as evidence for the existence of spillover effects from human capital externalities. Based on our results from Paper II, which suggest that increasing the regional share of highly qualified workers by one percent raises wages of highly qualified workers by about 1.8 percent, we first determine region specific wage effects from human capital externalities. Subtracting this effect from average wages of highly qualified workers, we obtain average wages net of productivity effects from intra-regional human capital externalities.

Table I displays average wages of highly qualified workers that would prevail in the sixteen best paying regions in the absence of intra-regional social returns to human capital. Map II extends the evidence to all regions in Western Germany. Two insights emerge. First, since agglomeration and aggregate levels of education are closely correlated, average wages drop most notably in large cities, corroborating that higher levels of education in cities play a significant role for the existence of urban wage premia. Second, in the absence of intra-regional human capital externalities, the highest paying regions turn out to be those peripheral to skilled regions. These two findings virtually hold for all skilled cities and the regions surrounding them, including Munich, Stuttgart, Frankfurt, the Ruhr area, Hannover, and Hamburg.

These empirical regularities suggest that higher productivity in skilled cities extends into neighboring regions (see Eckey/Kosfeld/Türck 2007). In general, human capital externalities are likely to transcend regional borders through the diffusion of productivity relevant information in shared labor markets.² With the existence of shared labor markets, productivity in peripheral regions rises because firms are able to acquire technological knowledge through the turnover of highly qualified workers (Almeida/Kogut 1999). Furthermore, our results from Paper III indicate that workers and firms benefit from improved job matching opportunities in a larger market for skills. Thus, with the potential of human capital externalities to transcend regional borders through shared labor markets, contemporary regional wage structures are likely to be shaped by the extent to which workers have access to skilled labor markets. Evidence from a number of regions confirms the relevance of labor market integration as a tool for increasing wages and productivity in neighboring regions. The two most skilled regions stand out as prime examples. In fact, the Rhine-Main area has benefitted greatly from a near to complete labor market integration with its local capital Frankfurt. Similarly, Bavarian regions, with Starnberg and Augsburg being the most prominent, incur substantial productivity benefits from sharing a common labor market for highly qualified workers with the city of Munich.

Given the potential of human capital externalities to unfold effects across regional borders, promoting a further integration of regional labor markets might be a pivotal strategy for regional policy to increase efficiency and equality alike.³ With the

² Given the close correlation of agglomeration and aggregate education, the spatial autocorrelation of wages might be driven by interregional spillovers from agglomeration externalities, or from social returns to human capital. Without spatial proximity matrices, i.e. information on the 'neighborhoodness' of regions, we cannot disentangle the relative size of both types of spillovers. However, due to the correlation of agglomeration and aggregate education our general policy implications, i.e. that integrating regional labor markets enhances external productivity benefits from localized increasing returns, are largely independent of the exact source of such spillover effects.

³ The optimal size of labor markets in order to maximize the gains from human capital externalities depends on the attenuation of productivity enhancing effects from aggregate education in space. First evidence indicates that human capital externalities are likely to range far. In fact, Fu (2007) and

existence of social returns to education, connecting low-skilled regions to skilled labor markets through investments into infrastructure is likely to induce a process of conditional wage convergence between neighboring regions. This convergence is of a conditional rather than an absolute nature because wage effects in peripheral regions have to be discounted by distance and adjusted to specific regional peculiarities.

In addition to raising wages through the process of conditional convergence, furthering an interregional integration of labor markets is likely to stimulate genuine employment and productivity growth in peripheral regions, if these become attractive locations for highly qualified workers themselves. If peripheral regions are well connected to skilled regions, highly qualified workers might decide to move there in order to benefit from enhanced productivity while at the same time avoiding urban disamenities from congestion.⁴ Their presence in peripheral regions in turn increases the attractiveness of a region and might thereby induce a process of sustainable growth. In fact, a large literature shows that regional employment growth increases with regional aggregate skill levels (Simon/Nardinelli 2002, Glaeser/Shapiro 2003, Südekum 2008). Such growth effects are attributable to the productivity enhancing nature of aggregate human capital on the one hand, and to local amenity effects from education on the other hand (Shapiro 2006). Amenity effects from human capital arise if individuals gain utility from living and working in educated environments. Like productivity effects, they can be regarded as local human capital externalities due to their localized and uncompensated nature.

Promoting an integration of regional labor markets is therefore likely to not only lead to conditional wage convergence, but might even yield sustained employment and productivity growth in peripheral regions. Such growth effects from labor market integration are arguably far more important for long term regional development than effects from conditional convergence alone. Prime examples in this respect are peripheral regions like Augsburg, Aschaffenburg and Schwäbisch-Gmünd, which are

Rosenthal/Strange (2008) show that although human capital externalities decay very quickly initially, significant effects prevail beyond fifty miles.

⁴ Investments into infrastructure are certainly at the forefront of policy measures aiming to foster the integration of regional labor markets. Yet, Glaeser/Gyourko/Saks (2006) emphasize the importance of housing policy as an additional tool for regional integration. In fact, regional governments have substantial influence on regional housing prices through regulations on the designation of land-use areas and the supply of construction permits. From the perspective of efficiency, the authors argue that by expanding the size of developable areas in skilled cities governments can induce a decline in housing prices and, through subsequent population growth, increase the number of workers which benefit from human capital externalities. With respect to promoting regional equality, their argument can be turned on its head. Since the regional distribution of highly qualified workers is likely to be influenced by regional differences in housing prices, peripheral regions could attract highly qualified workers through issuing construction permits so as to widen the gap in land prices. However, two caveats apply. First, such policies do not work without the provision of infrastructure which guarantees access to skilled labor markets. Second, like investments in infrastructure, such policies should be coordinated and planned on a higher political level (e.g. the Ministries for Spatial Planning of the *Länder*) so as to avoid inefficient competition between regions.

located close to the skilled labor markets of Munich, Frankfurt and Stuttgart. All of them have increased their attractiveness as locations for highly qualified workers by integrating their labor markets with that of their respective capital and have by now become home to highly qualified workers and skilled industries themselves.

Summing up, we regard the integration of labor markets as a promising strategy for increasing the overall social returns to human capital, and for promoting regional wage equality. However, due to its limited geographical scope this strategy is not a panacea for all regions alike. Naturally, the potential of labor market integration to raise productivity and wages is restricted to regions adjacent to skilled labor markets. If the distance to skilled labor markets becomes too large to be bridged through investments into infrastructure, recurring to 'traditional' regional education policy might be the only viable option for peripheral regions to also incur wage gains from productivity enhancing external effects from human capital. In order to avoid the pitfalls of regional education policy and to deliver sustainable productivity and wage growth, investments into tertiary education in remote regions should be complemented by measures to encourage labor demand for highly qualified workers. Attracting skill intensive industries to peripheral regions might allow such regions to reap the gains from investments made into human capital. Specifically, a close cooperation between universities and local firms, which has a longstanding tradition in the US, provides valuable opportunities to keep graduates in local labor markets and to stimulate sustainable wage and employment growth (Jaffe 1989). With respect to Germany, current initiatives to promote technology and knowledge clusters in remote regions, which encourage collaboration between universities and firms (e.g. in Jena), are promising attempts to overcome the exclusive focus on universities as engines of regional development and to arrive at sustainable strategies for remote regions to finally also reap benefits from regional human capital externalities (Audretsch/Lehmann/Warning 2005).

3. The Design of Regional Policies: The European Union

Promoting regional competitiveness and equality in standards of living have over time emerged as dual objectives of European policies. With the adoption of the Single European Act in 1986, the European Union has established the advancement of social and economic cohesion through active regional policies as a political objective, which complements the European Union's mandate of increasing productivity and growth through market integration. Given the substantial role of aggregate education for regional productivity and growth, enhancing the scope of regional human capital externalities through the integration of regional labor markets appears to be a viable

strategy for European policies to further both objectives alike. The recommendations we made with respect to the design of efficiency and equality enhancing regional and educational policies in Germany therefore by and large apply on the European level.

The strength of the European Union compared to the respective nation states lies in its ability to bridge regional labor markets across borders by removing legal, infrastructural, and psychological barriers to mobility. With respect to the former, a number of directives ban any kind of discrimination against foreign workers. These regulations, which after periods of transition are presently also coming into effect with respect to workers from Eastern Europe, have established the free movement of workers across all regions in Europe. Such anti-discrimination policies further the integration of cross-border labor markets which would otherwise have remained separated by policies on the preferential treatment of national workers. The process of removing legal barriers is complemented by regional policies that aim to connect regions through investments into infrastructure. Expenditure for structural policies is substantial, covering about thirty billion Euros in 2007. Finally and more subtly, the European Union contributes to the integration of labor markets by successively establishing the mentality that regions across Europe together form one single European labor market, which exists beyond national borders.

The close labor market integration between Trier and Luxemburg, made possible by the removal of legal, infrastructural, and psychological borders between two nation states provides an excellent example for the benefits peripheral regions can incur from gaining access to a skilled labor market. Thus, in addition to incurring substantial increases in wage levels, Trier has increasingly become home to highly qualified workers, which provides a strong base for future economic growth. Following this example, peripheral regions are well advised to foster the labor market integration with skilled regions in order to make productivity and amenity effects from human capital externalities accessible to highly and non-highly qualified workers alike.

References

- Almeida, Paul and Bruce Kogut. 1999. Localization of Knowledge and the Mobility of Engineers in Regional Networks. *Management Science* 45: 905-17.
- Audretsch, David B., Erik E. Lehmann and Susanne Warning. 2005. University Spillovers and New Firm Location. *Research Policy* 34: 1113-22.
- Bound, John, Jeffrey Groen, G. Gabor Kezdi and Sarah Turner. 2004. Trade in University Training: Cross-State Variation in the Production and Stock of College-Educated Labor. *Journal of Econometrics* 121: 143-73.
- Eckey, Hans-Friedrich, Reinhold Kosfeld and Matthias Türck. 2007. Regionale Entwicklung mit und ohne räumliche Spillover Effekte. *Jahrbuch für Regionalwissenschaft* 27: 23-42.
- Fu, Shihe. 2007. Smart Café Cities: Testing Human Capital Externalities in the Boston Metropolitan Area. *Journal of Urban Economics* 61: 86-111.
- Glaeser, Edward L. and Joshua D. Gottlieb. 2008. The Economics of Place Making Policies. *NBER Working Paper* 14373.
- Glaeser, Edward L., Joseph Gyourko and Raven E. Saks. 2006. Urban Growth and Housing Supply. *Journal of Economic Geography* 6: 71-89.
- Glaeser, Edward L. and Jesse M. Shapiro. 2003. Urban Growth in the 1990s: Is City Living Back? *Journal of Regional Science* 43: 139-65.
- Jaffe, Adam B. 1989. Real Effects of Academic Research. *American Economic Review* 79: 957-70.
- Krueger, Alan B. and Mikael Lindahl. 1999. Education for Growth in Sweden and the World. *Swedish Economic Policy Review* 6: 289-339.
- Moretti, Enrico. 2004. Estimation the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data. *Journal of Econometrics* 121: 175-212.
- OECD. 2007. Understanding the Regional Contribution of Higher Education Institutions: A Literature Review. OECD Research Report 09/2007.
- Rosenthal, Stuart S. and William C. Strange. 2008. The Attenuation of Human Capital Spillovers. *Journal of Urban Economics* 64: 373-389.
- Shapiro, Jesse M. 2006. Smart Cities: Explaining the Relationship between City Growth and Human Capital. *Review of Economics and Statistics* 88: 389-432.
- Simon, Curtis J. and Clark Nardinelli. 2002. Human Capital and the Rise of American Cities 1900-1990. *Regional Science and Urban Economics* 32: 59-96.
- Südekum, Jens. 2005. The Pitfalls of Regional Education Policy. *FinanzArchiv* 61: 327-52.
- Südekum, Jens. 2008. Convergence of the Skill Composition across German Regions. *Regional Science and Urban Economics* 38: 148-59.
- Tetsch, Friedrich. 1994. 25 Jahre Gesetz über die Gemeinschaftsaufgabe 'Verbesserung der regionalen Wirtschaftsstruktur'; in: Blien, Uwe, Hayo Herrmann and Martin Koller (eds.) *Regionalentwicklung und regionale Arbeitsmarktpolitik – Konzepte zur Lösung regionaler Arbeitsmarktprobleme?* Nuremberg: Institute for Labor and Employment Research.

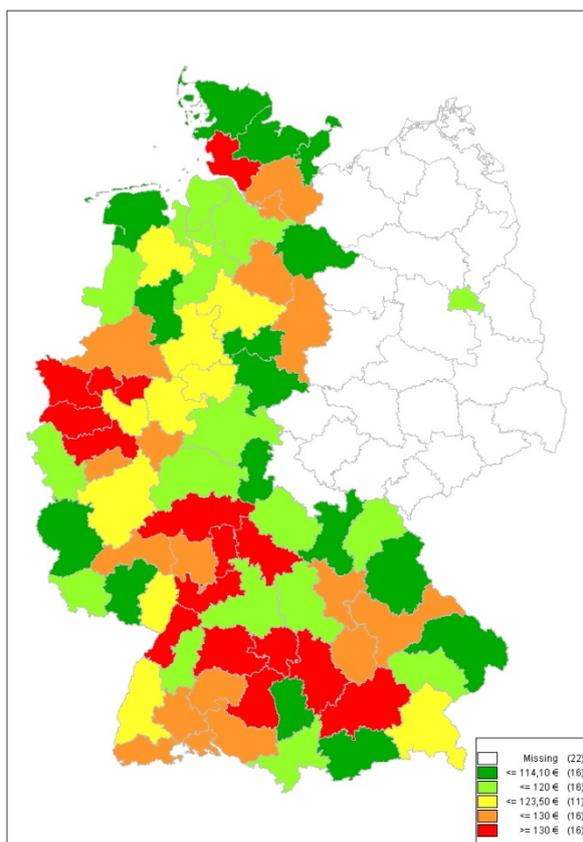
Appendix

Table I – Regional Wages with and without Intra-Regional Human Capital Externalities, 2001

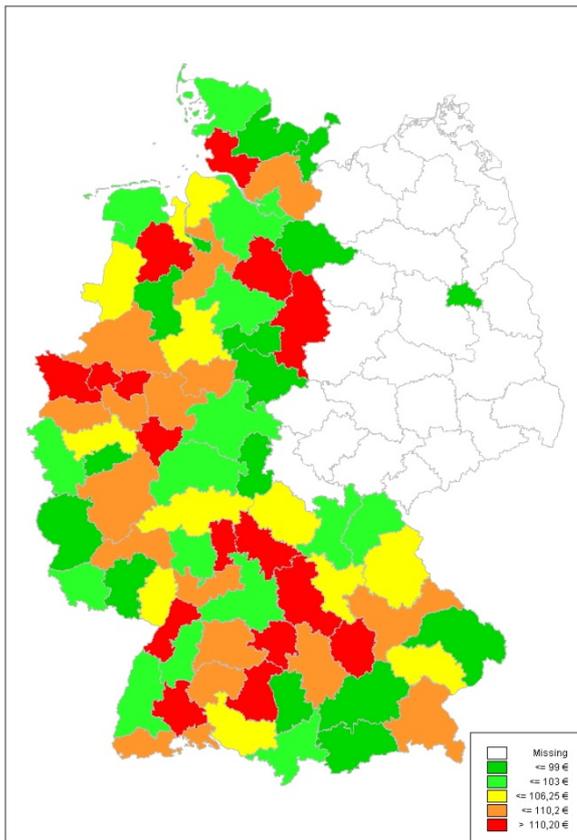
Region	Core City	\bar{O} Wages for HQ	\bar{O} Wages w/o HCE	Δ Wages
Ostwürttemberg	Schwäbisch-Gmünd	141,30	126,64	14,66
Rhein-Main	Frankfurt	138,66	104,98	33,68
München	München	137,58	98,55	39,03
Rhein-Neckar	Mannheim/Heidelberg	136,29	109,23	27,06
Stuttgart	Stuttgart	135,68	107,50	28,18
Bay. Untermain	Aschaffenburg	134,19	121,87	12,32
Mittlerer Oberrhein	Karlsruhe	133,98	110,60	23,38
Donau Iller	Ulm	133,88	113,22	20,66
Würzburg	Würzburg	133,20	115,97	17,23
Schleswig-Holstein Südwest	Steinburg	131,82	118,23	13,59
Emscher-Lippe	Recklinghausen/Bottrop	131,45	115,83	15,62
Köln	Köln	130,63	105,42	25,21
Dortmund	Dortmund	130,44	110,25	20,19
Augsburg	Augsburg	130,41	110,08	20,33
Duisburg/Essen	Duisburg/Essen	130,14	110,61	19,53
Düsseldorf	Düsseldorf	130,02	107,64	22,38

Notes: The column titled *Share of HQ* contains the regional share of highly qualified workers, as measured by the percentage share of workers within a regional workforce holding a degree from a university or a technical college; the column \bar{O} Wages for HQ contains the raw regional average daily gross wage for highly qualified workers in 2001; the column \bar{O} Wages without HCE contains the regional wages that would prevail in the absence of any human capital externalities, calculated on the basis of our results obtained in Paper II, i.e. that wages rise by 1.8 percent with each additional percentage point of highly qualified workers within a regional workforce; shaded regions belong to the sixteen most skilled regions in Western Germany.

Map I - Regional Wages of Highly Qualified Workers, 2001



Map II – Regional Wages without Intra-Regional Human Capital Externalities, 2001



Full List of References

- Abel, Jason R. and Todd M. Gabe. 2008. Human Capital and Economic Activity in Urban America. *Staff Report* No. 332. New York: Federal Reserve Bank.
- Acemoglu, Daron. 1996. A Microfoundation for Social Increasing Returns in Human Capital Accumulation. *Quarterly Journal of Economics* 111: 779-804.
- Acemoglu, Daron and Joshua Angrist. 2000. How Large Are Human Capital Externalities? Evidence from Compulsory Schooling Laws; in: Bernanke, Ben and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual*. Cambridge, MA: MIT Press.
- Acs, Zoltan J. and Catherine Armington. 2004. The Impact of Geographic Differences in Human Capital on Service Firm Formation Rates. *Journal of Urban Economics* 56: 244-78.
- Acs, Zoltan J. and David B. Audretsch. 1988. Innovation in Large and Small Firms: An Empirical Analysis. *American Economic Review* 78: 678-90.
- Aghion, Philippe and Peter Howitt. 1992. A Model of Growth through Creative Destruction. *Econometrica* 60: 323-51.
- Almeida, Paul and Bruce Kogut. 1999. Localization of Knowledge and the Mobility of Engineers in Regional Networks. *Management Science* 45: 905-17.
- Alonso-Villar, Olga. 2002. Urban Agglomeration: Knowledge Spillovers and Product Diversity. *The Annals of Regional Science* 36: 551-73.
- Anastassova, Lubomira. 2006. Productivity Differences and Agglomeration Across Districts of Great Britain. *CERGE-EI Working Paper* 289. Charles University of Prague, Czech Republic.
- Angrist, Joshua and Alan B. Krueger. 1991. Does Compulsory School Attendance Affect Schooling and Earnings? *Quarterly Journal of Economics* 106: 979-1014.
- Angrist, Joshua and Alan B. Krueger. 2001. Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments. *Journal of Economic Perspectives* 15: 69-85.
- Arrow, Kenneth. 1962. The Economic Implications of Learning by Doing. *The Review of Economic Studies* 29: 155-73.
- Arzaghi, Mohammad and J. Vernon Henderson. 2008. Networking Off Madison Avenue. *Review of Economic Studies* 75: 1011-38.
- Audretsch, David B. and Maryann P. Feldman. 1996. R&D Spillovers and the Geography of Innovation and Production. *American Economic Review* 86: 630-40.
- Audretsch, David B. and Maryann P. Feldman. 2004. Knowledge Spillovers and the Geography of Innovation; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Audretsch, David B., Erik E. Lehmann and Susanne Warning. 2005. University Spillovers and New Firm Location. *Research Policy* 34: 1113-22.
- Bacolod, Marigee, Bernardo Blum and William C. Strange. 2009. Skills in the City. *Journal of Urban Economics* 65: 136-53.
- Baldwin, John, Timothy Dunne and John Haltiwanger. 1998. A Comparison of Job Creation and Job Destruction in Canada and the United States. *Review of Economics and Statistics* 80: 347-56.
- Bartel, Ann P. and George J. Borjas. 1978. Wage Growth and Job Turnover: An Empirical Analysis. *NBER Working Paper* 285.

- Baum, Christopher F., Mark E. Schaffer and Steven Stillmann. 2003. Instrumental Variables and GMM: Estimation and Testing. *The Stata Journal* 3: 1-31.
- Battu, Harminder, Robert McMaster and Michael White. 2002. Tenure and Employment Contracts – An Empirical Investigation. *Journal of Economic Studies* 29: 131-49.
- Bayer, Patrick, Stephen L. Ross and Giorgio Topa. 2008. Place of Work and Place of Residence: Informal Hiring Networks and Labor Market Outcomes. *Journal of Political Economy* 116: 1150-96.
- Becker, Gary S. 1975. *Human Capital – A Theoretical and Empirical Analysis with Special Reference to Education*. Chicago: University of Chicago Press.
- Beeson, Patricia E. 1991. Amenities and Regional Differences in Returns to Worker Characteristics. *Journal of Urban Economics* 30: 224-41.
- Bundesforschungsanstalt für Landeskunde und Raumordnung. 1996. Neuabgrenzung der Raumordnungsregionen. *Mitteilungen und Informationen der BfLR*: 4-5.
- Birch, David. 1987. *Job Creation in America: How Our Smallest Companies Put The Most People to Work*. New York: Macmillan, Free Press; London: Collier Macmillan.
- Black, Duncan and Vernon Henderson. 1999. A Theory of Urban Growth. *The Journal of Political Economy* 107: 252-84.
- Blanchflower, David G. and Andrew J. Oswald. 1990. The Wage Curve. *Scandinavian Journal of Economics* 92: 215-35.
- Bleakley, Hoyt and Jeffrey Lin. 2007. Thick-Market Effects and Churning in the Labor Market: Evidence from U.S. Cities. *Reserve Bank of Philadelphia Working Paper* 07-23.
- Blien, Uwe. 2003. Die Lohnkurve – Auswirkungen der regionalen Arbeitslosigkeit auf das Lohnniveau. *Mitteilungen aus der Arbeitsmarkt- und Berufsforschung* 4: 439-60.
- Blien, Uwe and Helge Sanner. 2006. Structural Change and Regional Employment Dynamics. *IAB Discussion Paper* 06/2006. Nuremberg.
- Boeri, Tito and Ulrich Cramer. 1992. Employment Growth, Incumbents and Entrants. *International Journal of Industrial Organization* 10: 545-65.
- Boorman, Scott A. 1975. A Combinatorial Model for Transmission of Job Information through Contact Networks. *The Bell Journal of Economics* 6: 216-49.
- Borjas, George J. 1987. Self-Selection and the Earnings of Immigrants. *American Economic Review* 77: 531-53.
- Bound, John, Jeffrey Groen, G. Gabor Kezdi and Sarah Turner. 2004. Trade in University Training: Cross-State Variation in the Production and Stock of College-Educated Labor. *Journal of Econometrics* 121: 143-73.
- Briant, Anthony, Pierre-Philippe Combes and Miren Lafourcade. 2008. Do the Size and Shape of Spatial Units Jeopardize Economic Geography Estimations? *CEPR Discussion Paper* No. 6928.
- Brock, William A. and Steven N. Durlauf. 2001. Interactions-Based Models; in: Heckman, James J. and Edward Leamer (eds.) *Handbook of Econometrics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Brueckner, Jan K., Jacques F. Thisse and Yves Zenou. 1999. Why is Central Paris Rich and Downtown Detroit Poor? An Amenity Based Theory. *European Economic Review* 43: 91-107.
- Burgess, Simon, Julia Lane and David Stevens. 2000. Job Flows, Worker Flows, and Churning. *Journal of Labor Economics* 18: 473-502.

- Calvo-Armegnol, Antoni and Matthem O. Jackson. 2004. The Effects of Social Networks on Employment and Inequality. *American Economic Review* 94: 426-54.
- Calvo-Armegnol, Antoni and Matthem O. Jackson. 2007. Networks in Labor Markets: Wage and Employment Dynamics and Inequality. *Journal of Economic Theory* 132: 27-46.
- Carroll, Raymond J., David Ruppert, Ciprian Crainiceanu, Tor Tosteson and Margaret Karagas. 2004. Nonlinear and Nonparametric Regression and Instrumental Variables. *Journal of the American Statistical Association* 99: 736-50.
- Casper, Steven and Fiona Murray. 2005. Careers and Clusters: Analyzing the Career Network Dynamic of Biotechnology Clusters. *Journal of Engineering and Technology Management* 22: 51-74.
- Charlot, Sylvie and Gilles Duranton. 2004. Communication Externalities in Cities. *Journal of Urban Economics* 56: 581-613.
- Chinitz, Benjamin. 1966. Appropriate Goals for Regional Economic Policy. *Urban Studies* 3: 1-7.
- Chiswick, Barry R. 2005. *The Economics of Immigration*. Cheltenham UK: Edward Elgar Publishing.
- Ciccone, Antonio. 2002. Agglomeration Effects in Europe. *European Economic Review* 46: 213-28.
- Ciccone, Antonio and Robert Hall. 1996. Productivity and the Density of Economic Activity. *American Economic Review* 86: 54-70.
- Ciccone, Antonio and Giovanni Peri. 2006. Identifying Human-Capital Externalities: Theory with Applications. *Review of Economic Studies* 73: 381-412.
- Combes, Pierre-Philippe, Gilles Duranton and Laurent Gobillon. 2008. Spatial Wage Disparities: Sorting Matters! *Journal of Urban Economics* 63: 723-42.
- Combes, Pierre-Philippe, Miren Lafourcade and Thierry Mayer. 2005. The Trade Creating Effects of Business and Social Networks: Evidence from France. *Journal of International Economic* 66: 1-29.
- Combes, Pierre-Philippe, Laurent Linnemer and Michael Visser. 2008. Publish or Peer-Rish? The Role of Skills and Networks in Hiring Economics Professors. *Labour Economics* 15: 423-41.
- Combes, Pierre-Philippe, Thierry Magnac and Jean-Marc Robin. 2004. The Dynamics of Local Employment Growth in France. *Journal of Urban Economics* 56: 217-43.
- Combes, Pierre-Philippe and Henry G. Overman. 2004. The Spatial Distribution of Economic Activities in the European Union, in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Cowan, Robin. 2001. Expert Systems: Aspects of and Limitations to the Codifiability of Knowledge. *Research Policy* 30: 1355-72.
- Cowan, Robin and Nicolas Jonard. 2004. Network Structure and the Diffusion of Knowledge. *Journal of Economic Dynamics and Control* 28: 1557-75.
- Cramer, Ulrich and Martin Koller. 1988. Gewinne und Verluste von Arbeitsplätzen in Betrieben – der ‚Job Turnover‘-Ansatz. *Mitteilungen aus der Arbeitsmarkt- und Berufsforschung* 21: 361-77.
- Cutler, David M. and Edward L. Glaeser. 1997. Are Ghettos Good or Bad? *The Quarterly Journal of Economics* 112: 827-72.

- Dalmazzo, Alberto and Guido de Blasio. 2007. Production and Consumption Externalities of Human Capital: An Empirical Study for Italy. *Journal of Population Economics* 20: 359-82.
- Datcher, Linda. The Impact of Informal Networks on Quit Behavior. *The Review of Economics and Statistics* 65: 491-5.
- Davies, Jim B. 2002. Empirical Evidence on Human Capital Externalities. *Working Paper* 2003-11, Department of Finance, Canada.
- Davis, Steven and John Haltiwanger. 1992. Gross Job Creation, Gross Job Destruction, and Employment Reallocation. *Quarterly Journal of Economics* 107: 819-63.
- Davis, Steven and John Haltiwanger. 1999. Gross Job Flows; in: Ashenfelter, Orley and David Card (eds.). *Handbook of Labor Economics*. Elsevier: New York.
- Davis, Steven, John Haltiwanger and Scott Schuh. 1996. *Job Creation and Destruction*. Cambridge, MA: MIT Press.
- Desmet, Klaus and Esteban Rossi-Hansberg. 2009. Spatial Growth and Industry Age. Forthcoming: *Journal of Economic Theory*.
- Di Addario, Sabrina L. and Eleonora Patacchini. 2008. Wages and the City. Evidence from Italy. *Labour Economics* 15: 1040-61.
- Diamond, Charles A. and Curtis J. Simon. 1990. Industrial Specialization and the Returns to Labor. *Journal of Labor Economics* 8: 175-201.
- Donovan, M. Suzanne, John D. Bransford and James W. Pellegrino. 1999. *How People Learn: Bridging Theory and Practice*. Washington DC: National Academy Press.
- Drews, Nils 2006. Qualitätsverbesserung der Bildungsvariable in der IAB-Beschäftigtenstichprobe 1975 – 2001. *FDZ Methodenreport* No. 5, Federal Employment Agency, Nuremberg.
- Drews, Nils. 2007. Variablen der schwach anonymisierten Version der IAB-Beschäftigtenstichprobe 1975 – 2004. *FDZ Datenreport* 3/2007, Federal Employment Agency, Nuremberg.
- Driscoll, Marcy P. 1994. *Psychology of Learning for Instruction*. Needham, MA: Allyn&Bacon.
- DuMond, J. Michael, Barry Hirsch and David A. MacPherson 1999. Wage Differentials Across Labor Markets and Workers: Does Cost of Living Matter? *Economic Inquiry* 37: 577-98.
- Dumais, Guy, Glenn Ellison and Edward L. Glaeser. 2002. Geographic Concentration as a Dynamic Process. *The Review of Economics and Statistics* 84: 193-204.
- Dunne, Timothy, Mark J. Roberts and Larry Samuelson. 1989. Plant Turnover and Gross Employment Flows in the U.S. Manufacturing Sector. *Journal of Labor Economics* 7: 48-71.
- Duranton, Gilles. 2006. Human Capital Externalities in Cities: Identification and Policy Issues; in: Arnott, Richard and Daniel McMillen (eds.) *A Companion to Urban Economics*. Oxford: Blackwell Publishing Ltd.
- Duranton, Gilles. 2007. Urban Evolutions: The Fast, the Slow, and the Still. *American Economic Review* 97: 197-121.
- Duranton, Gilles. 2008. Spatial Economics; in: Durlauf, Steven N. and Lawrence E. Blume (eds.) *The New Palgrave Dictionary of Economics*, Second Edition. London: Palgrave Macmillan.

- Duranton, Gilles and Vassilis Monastiriotis. 2002. Mind the Gaps: The Evolution of Regional Earnings Inequalities in the UK, 1982-1997. *Journal of Regional Science* 42: 219-56.
- Duranton, Gilles and Diego Puga. 2000. Diversity and Specialization in Cities: Why, Where and When Does it Matter? *Urban Studies* 37: 533-56.
- Duranton, Gilles and Diego Puga. 2001. Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products. *American Economic Review* 91: 1454-77.
- Duranton, Gilles and Diego Puga. 2004. Micro-foundations of Urban Agglomeration Economies; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Eaton, Jonathan and Zvi Eckstein. 1997. Cities and Growth: Theory and Evidence from France and Japan. *Regional Science and Urban Economics* 27: 443-74.
- Eckey, Hans-Friedrich, Reinhold Kosfeld and Matthias Türck. 2006. Abgrenzung deutscher Arbeitsmarktregionen. *Raumforschung und Raumordnung* 64: 299-309.
- Eckey, Hans-Friedrich, Reinhold Kosfeld and Matthias Türck. 2007. Regionale Entwicklung mit und ohne räumliche Spillover Effekte. *Jahrbuch für Regionalwissenschaft* 27: 23-42.
- Ellison, Glenn and Drew Fudenberg. 1995. Word-of-Mouth Communication and Social Learning. *Quarterly Journal of Economics* 110: 93-125.
- Ellison, Glenn and Edward L. Glaeser. 1997. Geographic Concentration in US Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy* 105: 889-927.
- Ellison, Glenn, Edward L. Glaeser and William Kerr. 2007. What Causes Industry Agglomeration? – Evidence from Coagglomeration Patterns. *NBER Working Paper* 13068.
- Faberman, Jason R. 2002. Job Flows and Labor Dynamics in the U.S. Rust Belt. Bureau of Labor Statistics, Washington. *Monthly Labor Review* September 2002: 3-10.
- Faberman, Jason R. 2007. The Relationship between the Establishment Age Distribution and Urban Growth. *Federal Reserve Bank of Philadelphia Working Paper*.
- Fallick, Bruce, Charles A. Fleischman and James B. Rebitzer. 2006. Job Hopping in Silicon Valley: The Micro-Foundations of a High Technology Cluster. *The Review of Economics and Statistics* 88: 372-81.
- Farber, Henry S. 1999. Mobility and Stability: The Dynamics of Job Change in Labor Markets; in: Ashenfelter, Orley and David Card (eds.) *Handbook of Labor Economics* Vol 3. Amsterdam: Elsevier-North Holland.
- Findeisen, Sebastian and Jens Südekum. 2008. Industry Churning and the Evolution of Industries. *Journal of Urban Economics* 64: 326-39.
- Finney, Miles M. and Janet E. Kohlhase. 2007. The Effect of Urbanization on Labor Turnover. *Journal of Regional Science* 48: 311-28.
- Fischer, Claude S. 1982. *To Dwell Among Friends: Personal Networks in Town and City*. Chicago: University of Chicago Press.
- Fitzenberger, Bernd, Aderonke Osikominu and Robert Völter. 2006. Imputation Rules to Improve the Education Variable in the IAB Employment Subsample. *Discussion Paper* No. 5, University of Mannheim.

- Freedman, Matthew L. 2008. Job Hopping, Earning Dynamics, and Industrial Agglomeration in the Software Publishing Industry. *Journal of Urban Economics* 64: 590-600.
- Fritsch, Michael and Udo Brix. 2004. The Establishment File of the German Social Insurance Statistics. *Schmollers Jahrbuch* 124: 184-90.
- Fu, Shihe. 2005. What Has Been Capitalized into Property Values: Human Capital, Social Capital, or Cultural Capital? *CES Working Paper* 05-25. Washington: US Census Bureau.
- Fu, Shihe. 2007. Smart Café Cities: Testing Human Capital Externalities in the Boston Metropolitan Area. *Journal of Urban Economics* 61: 86-111.
- Gartner, Hermann. 2005. The Imputation of Wages above the Contribution Limit with the German IAB Employment Sample. *FDZ Methodenreport* No. 2, Federal Employment Agency, Nuremberg.
- Glaeser, Edward L. 1999. Learning in Cities. *Journal of Urban Economics* 46: 254-77.
- Glaeser, Edward L. 2005. Reinventing Boston: 1630-2003. *Journal of Economic Geography* 5: 119-53.
- Glaeser, Edward L. and Joshua D. Gottlieb. 2008. The Economics of Place Making Policies. *NBER Working Paper* 14373.
- Glaeser, Edward L., Joseph Gyourko and Raven E. Saks. 2006. Urban Growth and Housing Supply. *Journal of Economic Geography* 6: 71-89.
- Glaeser, Edward L., Hedi D. Kallal, Jose A. Scheinkman and Andrei Shleifer. 1992. Growth in Cities. *The Journal of Political Economy* 100: 1126-52.
- Glaeser, Edward L., Jed Kolko and Albert Saiz. 2001. Consumer City. *Journal of Economic Geography* 1: 27-50.
- Glaeser, Edward L. and David C. Maré. 2001. Cities and Skills. *Journal of Labor Economics* 19: 316-42.
- Glaeser, Edward L. and Albert Saiz. 2003. The Rise of the Skilled City. *Brookings-Wharton Papers on Urban Affairs* 5: 47-94.
- Glaeser, Edward L., Jose A. Scheinkman and Andrei Shleifer. 1995. Economic Growth in a Cross-Section of Cities. *Journal of Monetary Economics* 36: 117 - 43.
- Glaeser, Edward L. and Jesse M. Shapiro. 2003. Urban Growth in the 1990s: Is City Living Back? *Journal of Regional Science* 43: 139-65.
- Gould, Eric D. 2007. Cities, Workers, and Wages: A Structural Analysis of the Urban Wage Premium. *Review of Economic Studies* 74: 477-506.
- Granovetter, Mark. 1974. *Getting a Job – A Study of Contacts and Careers*. Cambridge, MA: Harvard University Press.
- Granovetter, Mark. 1983. The Strength of Weak Ties: A Network Theory Revisited. *Sociological Theory* 1: 201-33.
- Green, Francis, Stephen Machin and Alan Manning. 1996. The Employer-Size Wage Effect: Can Dynamic Monopsony Provide an Explanation? *Oxford Economic Papers* 48: 433-55.
- Grossetti, Michael. 2007. Are French Networks Different? *Social Networks* 29: 391-404.
- Haas, Anette. 2002. Regionale Mobilität am Arbeitsmarkt: Wohin nach der Berufsausbildung? Die Ost/West-Mobilität von jungen Fachkräften. *IAB Kurzbericht* 07/2002.

- Haisken-DeNew, John P. and Christoph M. Schmidt. 1997. Interindustry and Interregional Differentials: Mechanics and Interpretation. *The Review of Economics and Statistics* 79: 516-21.
- Haisken-DeNew, John P. and Johannes Schwarze. 1997. Regionale Lohn disparitäten in Deutschland 1984-1994 – Eine Analyse mit regionalisierten Daten des Sozio-Ökonomischen Panels. *Informationen zur Raumentwicklung* 1/2: 51-61.
- Halfdanarson, Benedikt, Daniel F. Heuermann and Jens Südekum. 2008. Human Capital Externalities and the Urban Wage Premium – Two Literatures and their Interrelations. *IZA Discussion Paper* 3493.
- Hamann, Silke, Gerhard Krug, Markus Köhler, Wolfgang Ludwig-Mayerhofer and Anne Hacket. 2004. Die IAB-Regionalstichprobe 1975 – 2001: IABS-R01. *ZA-Information* 55/2004.
- Hausman, Jerry A. 1978. Specification Tests in Econometrics. *Econometrica* 46: 1251-71.
- Helsley, Robert W. and William C. Strange. 1990. Matching and Agglomeration Economies in a System of Cities. *Regional Science and Urban Economics* 20: 189-212.
- Henderson, J. Vernon. 1986. Efficiency of Resource Usage and City Size. *Journal of Urban Economics* 19: 47-70.
- Henderson, J. Vernon. 2003. Marshall's Scale Economies. *Journal of Urban Economics* 53: 1-28.
- Henderson, Vernon, Ari Kuncuro and Matt Turner. 1995. Industrial Development in Cities. *The Journal of Political Economy* 103: 1067-90.
- Heuermann, Daniel F. 2008. Human Capital Externalities in Western Germany. *IAAEG Discussion Paper* 05/2008. University of Trier.
- Heuermann, Daniel F. 2009. Career Networks and Matching Externalities – Evidence on the Microeconomic Foundations of Human Capital Externalities. *IAAEG Discussion Paper* 01/2009. University of Trier.
- Hillmert, Steffen. 2004. Regional Mobility in Early Adulthood: the Impact of Qualifications. *Paper Prepared for the Annual Meeting of the European Research Network on Transition in Youth*, Nuremberg.
- Hirschman, Albert O. 1958. *The Strategy of Economic Development*. New Haven: Yale University Press.
- Holmes, Thomas J. and John J. Stevens. 2002. Geographic Concentration and Establishment Scale. *The Review of Economic and Statistics* 84: 682-90.
- Holmes, Thomas J. and John J. Stevens. 2004. The Spatial Distribution of Economic Activities in North America; in: Henderson, J. Vernon and Jacques-Francois Thisse (Eds.) *Handbook of Urban and Regional Economics*. Amsterdam: Elsevier-North Holland.
- Hoxby, Caroline M. 2000. Does Competition among Public Schools Benefit Taxpayers? *American Economic Review* 90: 1209-38.
- Ioannides, Yannis M. and Linda Datcher Loury. 2004. Job Information Networks, Neighborhood Effects, and Inequality. *Journal of Economic Literature* 62: 1056-93.
- Jacobs, Jane. 1961. *The Death and Life of Great American Cities*. New York: Random House.
- Jacobs, Jane. 1969. *The Economy of Cities*. New York: Random House.

- Jaffe, Adam B. 1989. Real Effects of Academic Research. *American Economic Review* 79: 957-70.
- Jaffe, Adam B., Manuel Trajtenberg and Rebecca Henderson. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics* 108: 577-98.
- Jeger, Mike J., Marco Pautasso, Ottmar Holdenrieder and Mike W. Shaw. 2007. Modelling Disease Spread and Control in Networks: Implications for Plant Science. *New Phytologist* 174: 279-97.
- Jovanovic, Boyan. 1979. Job Matching and the Theory of Turnover. *Journal of Political Economy* 87: 972-90.
- Jovanovic, Boyan. 1982. Selection and the Evolution of Industry. *Econometrica* 50: 649-70.
- Jovanovic, Boyan and Yaw Nyarko. 1995. The Transfer of Human Capital. *Journal of Economic Dynamics and Control* 19: 1033-64.
- Jovanovic, Boyan and Rafael Rob. 1989. The Growth and Diffusion of Knowledge. *Review of Economic Studies* 56: 569-82.
- Jurajda, Stepan. 2004. Are There Increasing Returns to Local Concentration of Skills? – Evidence on Wages and Returns to Education in Transition. *CERGE-EI Working Paper 260*. Prague: Czech National Bank.
- Kaldor, Nicholas. 1970. The Case for Regional Policies. *Scottish Journal of Political Economy* 17: 337-48.
- Kanbur, Ravi and Anthony J. Venables. 2005. Spatial Inequality and Development; in: Venables, Anthony J. (ed.) *Spatial Inequality and Development*. Oxford, London: Oxford University Press.
- Katz, Lawrence F. and Kevin M. Murphy. 1992. Changes in Relative Wages, 1963-87: Supply and Demand Factors. *Quarterly Journal of Economics* 107: 35-78.
- Kelejian, Harry H. 1971. Two-Stage Least Squares and Econometric Systems Linear in Parameters but Nonlinear in the Endogenous Variable. *Journal of the American Statistical Association* 66: 373-74.
- Kim, Sunwoong. 1990. Labor Heterogeneity, Wage Bargaining, and Agglomeration Economies. *Journal of Urban Economics* 28: 160-177.
- Kim, Bonggeun. 2004. The Wage Gap between Metropolitan and Non-metropolitan Areas. *Discussion Paper* 189, Australasian Meetings 2004, Econometric Society.
- Kirby, Simon and Rebecca Riley. 2008. The External Returns to Education: Evidence Using Repeated Cross-Sections. *Labour Economics* 15: 619-30.
- Kolko, Jed. 2008. Urbanization, Agglomeration, and Co-Agglomeration of Service Industries. Forthcoming: *NBER Conference Volume on Agglomeration*.
- Kremer, Michael. 1997. How Much Does Sorting Increase Inequality? *Quarterly Journal of Economics* 112: 115-39.
- Krueger, Alan B. and Mikael Lindahl. 1999. Education for Growth in Sweden and the World. *Swedish Economic Policy Review* 6: 289-339.
- Krueger, Alan B. and Larry H. Summers. 1988. Efficiency Wages and the Inter-Industry Wage Structure. *Econometrica* 56: 259-93.
- Krugman, Paul. 1991. *Geography and Trade*. Cambridge, MA: MIT Press.
- Kuznets, Simon. 1955. Economic Growth and Income Inequality. *The American Economic Review* 45: 1-28.

- Lehmer, Florian and Johannes Ludsteck. 2008. The Returns to Job Mobility and Inter-Regional Migration. *IAB Discussion Paper 6/2008*, Institute for Labour and Employment Research.
- Lehmer, Florian and Joachim Möller. 2008. Group Specific Effects of Interregional Mobility on Earnings – A Microdata Analysis for Germany. *Regional Studies* 42: 657-74.
- Lehmer, Florian and Joachim Möller. 2009. Interrelations between the Urban Wage Premium and Firm-Size Wage Differentials: A Micro Data Cohort Analysis for Germany. Forthcoming: *Annals of Regional Science*.
- Liu, Zhiqiang. 2007. The External Returns to Education: Evidence from Chinese Cities. *Journal of Urban Economics* 61: 542-64.
- Lucas, Robert E. 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* 22: 3-42.
- Mamede, Ricardo. 2006. Towards an Integrated Approach to Industry Dynamics and Labour Mobility. MPRA Paper 3994. University Library Munich.
- Mankiw, N. Gregory, David Romer and David N. Weil. 1992. A Contribution to the Empirics of Economic Growth. *Quarterly Journal of Economics* 107: 407-37.
- Marshall Alfred. 1890. *Principles of Economics*. London: Macmillan and Co.
- Mincer, Jacob. 1974. *Schooling, Experience, and Earnings*. New York: NBER.
- Mincer, Jacob and Boyan Jovanovic. 1981. Labor Mobility and Wages; in: Rosen, Sherwin (ed.) *Studies in Labor Markets*. Chicago: University of Chicago Press.
- Mion, Giordano and Paolo Naticchioni. 2009. The Spatial Sorting and Matching of Skills and Firms. *Canadian Journal of Economics* 42: 28-55.
- Möller, Joachim and Anette Haas. 2003. The Agglomeration Differential Reconsidered: An Investigation with German Micro Data 1984-1997; in: Bröcker, Johannes, Dirk Dohse and Rüdiger Soltwedel (eds.). *Innovation Clusters and Interregional Competition*. Berlin: Springer.
- Moretti, Enrico. 2000. Do Wages Compensate for Risk of Unemployment? Parametric and Semiparametric Evidence from Seasonal Jobs. *Journal of Risk and Uncertainty* 20: 45-66.
- Moretti, Enrico. 2004a. Human Capital Externalities in Cities; in: Henderson, James V. and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Elsevier: San Diego, Oxford, London.
- Moretti, Enrico. 2004b. Estimation the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data. *Journal of Econometrics* 121: 175-212.
- Moretti, Enrico. 2004c. Workers' Education, Spillovers, and Productivity: Evidence from Plant-Level Production Functions. *American Economic Review* 94: 656-690.
- Moretti, Enrico. 2008. Real Wage Inequality. *NBER Working Paper* 14370.
- Moulton, Brent R. 1990. An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units. *The Review of Economics and Statistics* 72: 334-38.
- Munshi, Kaivan. 2003. Networks in the Modern Economy: Mexican Migrants in the U.S. Labor Market. *The Quarterly Journal of Economics* 118: 549-99.
- Myrdal, Gunnar. 1957. *Economic Theory and Underdeveloped Regions*. New York: Ducksworth.

- Newey, Whitney K. 1990. Efficient Instrumental Variables Estimation of Nonlinear Models. *Econometrica* 58: 809-37.
- Newey, Whitney K. and Kenneth D. West. 1987. A Simple, Positive Semi-Definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix. *Econometrica* 55: 703-8.
- Munshi, Kaivan. 2003. Networks in the Modern Economy: Mexican Migrants in the U.S. Labor Market. *The Quarterly Journal of Economics* 118: 549-99.
- Muravyev, Alexander. 2008. Human Capital Externalities: Evidence from the Transition Economy of Russia. *Economics of Transition* 16: 415-43.
- Nelson, Richard R. and Edmund S. Phelps. 1966. Investment in Humans, Technological Diffusion, and Economic Growth. *American Economic Review* 56: 69-75.
- OECD. 2007. Understanding the Regional Contribution of Higher Education Institutions: A Literature Review. OECD Research Report 09/2007.
- Openshaw, Stan and Peter J. Taylor. 1979. A Million or so Correlation Coefficients: Three Experiments on the Modifiable Areal Unit Problem; in: Wrigley, Neil (ed.) *Statistical Applications in the Spatial Sciences*. London: Pion.
- Ottaviano, Gianmarco and Jacques-Francois Thisse. 2004. Agglomeration and Economic Geography; in: Henderson, J. Vernon and Jacques-Francois Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4: Cities and Geography. Amsterdam: Elsevier-North Holland.
- Overman, Henry G. and Diego Puga. 2008. Labour Pooling as a Source of Agglomeration: An Empirical Investigation. *Working Paper 2008-05*. IMDEA, University of Madrid.
- Peri, Giovanni. 2002. Young Workers, Learning and Agglomerations. *Journal of Urban Economics* 52: 582-607.
- Podolny, Joel M. and James N. Baron. 1997. Resources and Relationships: Social Networks and Mobility in the Workplace. *American Sociological Review* 62: 673-93.
- Polanyi, Michael. 1958. *Personal Knowledge: Towards a Post-Critical Philosophy*. Chicago. Chicago: University of Chicago Press.
- Rauch, James E. 1993. Productivity Gains from Geographic Concentration of Human Capital: Evidence from the Cities. *Journal of Urban Economics* 34: 380-400.
- Roback, Jennifer. 1982. Wages, Rents, and the Quality of Life. *Journal of Political Economy* 90: 1257-78.
- Rogers, William. 1993. sg17: Regression Standard Errors in Clustered Samples. *Stata Technical Bulletin* 13: 19-23.
- Romer, Paul M. 1986. Increasing Returns and Long-Run Growth. *Journal of Political Economy* 94: 1002-37.
- Rosenthal, Stuart S. and William C. Strange. 2001. The Determinants of Agglomeration. *Journal of Urban Economics* 50: 191-229.
- Rosenthal, Stuart S. and William C. Strange. 2004. Evidence on the Nature and Sources of Agglomeration Economies; in: Henderson, J. Vernon and Jacques F. Thisse (eds.) *Handbook of Regional and Urban Economics* Vol. 4. Amsterdam: Elsevier-North Holland.
- Rosenthal, Stuart S. and William C. Strange. 2008. The Attenuation of Human Capital Spillovers. *Journal of Urban Economics* 64: 373-389.
- Rudd, Jeremy. 2000. Empirical Evidence on Human Capital Spillovers. *FEDS Discussion Paper* 2000-46.

- Santarelli, Enrico and Macro Vivarelli. 2007. Entrepreneurship and the Process of Firms' Entry, Survival and Growth. *Industrial and Corporate Change* 16: 455-88.
- Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Schultz, Theodore W. 1963. *The Economic Value of Education*. New York, London: Columbia University Press.
- Scitovski, Tibor. 1954. Two Concepts of External Economies. *Journal of Political Economy* 62: 70-82.
- Shapiro, Jesse M. 2006. Smart Cities: Explaining the Relationship between City Growth and Human Capital. *The Review of Economics and Statistics* 88: 389-432.
- Simon, Curtis J. 1998. Human Capital and Metropolitan Employment Growth. *Journal of Urban Economics* 43: 223 – 43.
- Simon, Curtis J. 2004. Industrial Reallocation across US Cities, 1977-1997. *Journal of Urban Economics* 56: 119-43.
- Simon, Curtis J. and Clark Nardinelli. 2002. Human Capital and the Rise of American Cities 1900-1990. *Regional Science and Urban Economics* 32: 59-96.
- Simon, Curtis J. and John T. Warner. 1992. Matchmaker, Matchmaker: The Effects of Old Boy Networks on Job Match Quality, Earnings, and Tenure. *Journal of Labor Economics* 10: 306-30.
- Sobel, Joel. 2000. Economists' Models of Learning. *Journal of Economic Theory* 94: 241-61.
- Spengler, Anja. 2007. The Establishment History Panel. *FDZ Methodenreport*. Institute for Labor and Employment Research, Nuremberg.
- Stahl, Konrad and Uwe Walz. 2001. Will There Be a Concentration of Alikes? The Impact of Labor Market Structure on Industry Mix in the Presence of Product Market Shocks. *HWWA Discussion Paper* 140. Hamburg.
- Strawinski, Pawel. 2008. External Returns to Education in Poland. *MPRA Paper 11598*. University Library of Munich, Germany.
- Südekum, Jens. 2003. *Agglomeration and Regional Unemployment Disparities*. Frankfurt: Peter Lang.
- Südekum, Jens. 2005. The Pitfalls of Regional Education Policy. *FinanzArchiv* 61: 327-52.
- Südekum, Jens. 2006. Concentration and Specialization Trends in Germany since Re-Unification. *Regional Studies* 40: 861-73.
- Südekum, Jens. 2008. Convergence of the Skill Composition across German Regions. *Regional Science and Urban Economics* 38: 148-59.
- Tetsch, Friedrich. 1994. 25 Jahre Gesetz über die Gemeinschaftsaufgabe 'Verbesserung der regionalen Wirtschaftsstruktur'; in: Blien, Uwe, Hayo Herrmann and Martin Koller (eds.) *Regionalentwicklung und regionale Arbeitsmarktpolitik – Konzepte zur Lösung regionaler Arbeitsmarktprobleme?* Nuremberg: Institute for Labor and Employment Research.
- von Hippel, Eric. 1994. Sticky Information and the Locus of Problem Solving: Implications for Innovation. *Management Science* 40: 429-39.

- von Thünen, Johann Heinrich. 1826. *Der isolirte Staat in Beziehung auf Landwirthschaft und Nationalökonomie, oder Untersuchungen über den Einfluß, den die Getreidepreise, der Reichthum des Bodens und die Abgaben auf den Ackerbau ausüben*. Hamburg: Perthes.
- Watts, Duncan J. and Steven H. Strogatz. 1998. Collective Dynamics of Small-World Networks. *Letters to Nature* 393: 440-442.
- Weber, Adna F. 1899. *The Growth of Cities in the Nineteenth Century*. 3rd reprint, Ithaca, N.Y.: Cornell.
- Weber, Alfred. 1909. *Reine Theorie des Standortes*. Tübingen: Mohr.
- Welch, Finis. 1970. Education in Production. *Journal of Political Economy* 78: 35-59.
- Wheaton, William C. and Mark J. Lewis. 2002. Urban Wages and Labor Market Agglomeration. *Journal of Urban Economics* 51: 542-62.
- Wheeler, Christopher H. 2001. Search, Sorting, and Urban Agglomeration. *Journal of Labor Economics* 19: 879-99.
- Wheeler, Christopher H. 2006. Cities and the Growth of Wages among Young Workers: Evidence from the NLSY. *Journal of Urban Economics* 60:162-84.
- Wheeler, Christopher H. 2007. Do Localization Economies Derive from Human Capital Externalities? *Annals of Regional Science* 41: 31-50.
- Wheeler, Christopher H. 2008. Local Market Scale and the Pattern of Job Change among Young Men. *Regional Science and Urban Economics* 38: 101-18.
- Yankow, Jeffrey J. 2006. Why Do Cities Pay More? An Empirical Examination of Some Competing Theories of the Urban Wage Premium. *Journal of Urban Economics* 60: 139-61.

