Human Capital Externalities and Growth of High- and Low-Skilled Jobs

Jens Südekum
University of Duisburg-Essen
Mercator School of Management
Lotharstrasse 65
47057 Duisburg
jens.suedekum@uni-due.de
Phone: +49/(0)203/3792357

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Abstract (long)
Human capital is unequally distributed across cities or regions within a country. The way how the spatial distribution of human capital evolves over time sheds light on the strength of concentration forces for high-skilled workers, such as localised increasing returns to human capital. In this paper I analyse the impact of human capital on local employment growth for Western German regions (1977-2006). Two main empirical facts are established: "Skilled cities" in Western Germany grow faster. At the same time there is convergence of human capital shares across cities, i.e., high-skilled workers do not increasingly concentrate in space. Whereas the first fact (the "smart city hypothesis") similarly holds in Germany and in the US, there is a striking difference when it comes to the second fact. Some researchers have found an opposite trend of human capital divergence across US metropolitan areas. My findings suggest that human capital exhibits a different spatial trend in different countries. I present a theoretical model which shows that the spatial convergence trend does not imply that concentration forces for high-skilled workers are absent in Western Germany, but only that they are relatively weak compared to countervailing dispersion forces. I further discuss some reasons that may explain the differences between Western Germany and the US. I emphasise the role of the tax system and the impact of pro-dispersive regional policy in Europe.

Abstract (short)
In this paper I establish two main facts: "Skilled cities" in Western Germany grow faster. At the same time there has been a convergence of human capital shares across cities. This second fact is strikingly different in Germany than in the US. I develop a simple theoretical model to interpret these results. The model shows that spatial convergence of human capital does not imply that concentration forces for high-skilled workers (such as localised human capital externalities) are completely absent, but only that they are relatively weak.

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1) Introduction

Economic growth and urbanization are interrelated processes. Growth within a country does not occur uniformly across space and concentration of economic activity in cities fuels innovation and growth. The urban literature has discussed various micro-foundations for agglomeration effects. It is frequently argued that spatial concentration leads to pooling advantages on factor markets, more vital exchange of ideas and knowledge, higher innovation, linkages due to endogenous market size effects, and more learning.[1] According to Lucas' (1988) or Marshall's (1890) often cited contributions these scale economies may even be regarded as the fundamental reason for the existence of cities and agglomerations. The (relative) empirical importance of these agglomeration forces is far from clear today (Rosenthal and Strange, 2004). But for any of the mechanisms it seems plausible that human capital is an important catalyst. This suggests the presence of a *human capital externality* that is quite commonly used in endogenous growth theory (Lucas, 1988; Acemoglu, 1996), where non-decreasing returns to human capital act as the engine for sustained long-run growth in developed societies. Despite the massive implications for cross-country income differences (see e.g. Mankiw et al., 1992), Lucas himself emphasises that *local* environments are the natural spatial scale on which these externalities should be studied, since knowledge spillovers exhibit a rapid spatial decay (Audretsch and Feldmann, 1996).

This paper is concerned with the intra-national evolution of human capital over time, and its interrelations with local growth in Western Germany (1977-2006). Previous research in urban economics from the US has found a robust positive correlation between initial human capital intensity (measured by the employment share of college educated workers) and subsequent city employment growth (Glaeser et al., 1995; Simon, 1998, 2004; Simon and Nardinelli, 2002; Glaeser and Saiz, 2004; Shapiro, 2006). Less is known about *why* skilled cities grow faster than unskilled ones. It could be that human capital is simply correlated with other city

[1] For an overview of these and various related issues, the reader might refer to the recent *Handbook* by Henderson and Thisse (2004), in particular to the chapters by Duranton/Puga and Rosenthal/Strange

characteristics that are left out of the regression which causally drive employment growth. One such feature may be the city's industry structure. A city might strive not because it hosts a skilled body of employees, but because it is specialised in booming industries that use human capital intensively (Simon, 2004). Second, more educated cities might generate greater consumption amenities or quality of life, thereby attracting more individuals (Shapiro, 2006). Finally, the positive correlation may be due to the fact that more educated workers raise local productivity. Glaeser and Saiz (2004) argue that this last argument – productivity – is actually the most pervasive one. Controlling for a variety of other factors, including industry structure, does not eliminate the positive growth impact of human capital. And even though consumption amenities also play a significant role, as Shapiro (2006) shows, they tend to be relatively less important.

The literate has not yet come to grips, however, with the mechanism underlying the link between skill intensity and local productivity. Some recent papers that address the impact of human capital on local wages have put forward two competing, though not mutually exclusive theories: externalities and imperfect substitutability of input factors. Total factor productivity may depend endogenously on local human capital (as in Lucas, 1988), and the social returns exceed the private returns to education.[2] Yet, human capital can raise wages even in the absence of any spillover or market-mediated concentration force. In a straightforward neoclassical model with perfect competition, more educated workers in a city raise productivity and wages of low-skilled workers. If this increase is stronger than the wage decline for skilled workers, which is negatively related to their supply, the average wage in the city can actually increase. Moretti (2004a) and Ciccone and Peri (2006) have suggested strategies to identify the size of a potential human capital externality. Recent surveys of this literature are provided by Moretti (2004b) and Duranton (2006).

[2] This theory is underlying the seminal study by Rauch (1993), who finds that an increase in average schooling by one year increases wages of workers with unchanged education level by 3 to 5 per cent. Instead of direct technological spillovers, there may alternatively be pecuniary externalities arising from job search (Acemoglu, 1996) or from endogenous market size effect (Krugman, 1991).

In the present paper I analyse employment growth at the local level in order to shed light on whether complementarities or externalities are the main underlying cause for the link between education, productivity, and city growth. I start with a simple theoretical model on the link between human capital externalities and the spatial structure of the human capital distribution in a multi-region economy. The model predicts that growth of low-skilled jobs should depend positively on initial skill intensity. This arises as a matter of complementarities between education groups alone, and is reinforced by external effects. With respect to high-skilled jobs, employment growth should be higher in cities where educated workers are initially relatively scarce, unless some localised human capital externality is countervailing this "neoclassical" tendency. In other words, the effect of the initial human capital share on employment growth of high-skilled jobs is ambiguous and depends on the strength of possible human capital externalities. This prediction forms the basis for my subsequent empirical analysis.

I analyse the implications of the initial human capital share for local growth of high-skilled and low-skilled jobs across 326 Western German regions over the time period 1977-2006. I indeed find a robust positive impact on *total* employment growth at the local level. This result corroborates earlier findings for the US, and suggests that European economies behave similarly in this respect. Differentiating between skill groups, I find that initial skill intensity is strongly positively related to subsequent employment growth of low-skilled jobs (as expected). For high-skilled employment growth, however, the effect is significantly and robustly negative. Put differently, the positive impact of human capital on total local employment growth is due to the fact that low-skilled jobs grow faster than high-skilled jobs decline in initially skilled cities.

These empirical findings for Western Germany sharply contrast stylised facts from the US. A few recent papers (Moretti, 2004b; Berry and Glaeser, 2005; Wheeler, 2006) argue that there is a tendency of increasing inequality in the distribution of human capital across US cities and metropolitan areas. Relatively human capital abundant regions became increasingly skilled

over time, i.e., there has been a *divergence* of human capital in the US.[3] My results are, however, in line with recent findings for Western Germany by Suedekum (2008) who also finds a *convergence* of local human capital shares. The present contribution adds value to that study in several respects. Firstly, I present a model of human capital externalities and the spatial concentration of human capital that provides the underlying theoretical framework for the empirical analysis. Secondly, the empirical analysis in this paper is more detailed and more recent (until 2006), resorts to several estimation methods and provides a variety of additional robustness checks including an analysis that takes into account spatial dependency across the single regions. Thirdly, I expand on the interpretations of the results and on the comparison with the evidence from the US.

What are the (policy) implications of my empirical findings? My results cast doubts on "Silicon valley"-type stories according to which there is a self-reinforcing spatial concentration trend of human capital. High-skilled workers do not appear to move to places that are already skill intensive. This should be good news for mayors of small and peripheral places trying to attract human capital to their jurisdictions. But even though my findings seem to have a strong "neoclassical flavour", they do *not* imply that concentration forces such as localised human capital externalities are completely absent. Spatial convergence of high-skilled employment shares is still consistent with the mere existence of localised increasing returns to human capital, as will become clear from the theoretical model, provided they are not too strong. More generally, my results suggest that the intra-national spatial evolution of human capital differs across countries. This cross-country difference may be a factor that is related to sustained differences in aggregate growth performances which the literature has largely ignored so far. Certainly more research for further countries is needed in this area.

[3] Moretti (2004b) points out: "*Cities that had a relatively high fraction of educated individuals in 1990 experienced larger increases [in the fraction of educated workers] between 1990 and 2000 than cities that had a relatively smaller fraction of educated individuals that year. As a consequence, the distribution of human capital across cities became more unequal during the 1990s. […] But this tendency of increasing inequality in the distribution of human capital across US cities during the 1990s was not a new phenomenon, as it was already in place in the 1980s.*" - Berry and Glaeser (2005) obtain consistent results. They report that "*U.S. metropolitan areas with more college graduates in 1990 became increasingly skilled over the 1990s."*

The rest of this paper is organised as follows. In section 2 I present a simple theoretical model that helps to interpret the stylised facts. In section 3 I describe the data set and present a descriptive overview. The statistical analysis and the main results are presented in section 4. In section 5 I summarise the empirical facts for Western Germany, and I discuss the differences with the related evidence from the US.

2) Theoretical background

The following simple model illustrates the conflict between human capital externalities as a centripetal force for high-skilled workers, and two opposing centrifugal forces: housing scarcity, and a straightforward neoclassical supply effect according to which returns to human capital are lower in regions where high-skilled workers are abundant.

Consider an economy that consists of $c = 1,...,N$ cities or locations. There are two types of labour. High-skilled workers are assumed to be geographically mobile, whereas low-skilled workers are immobile. This assumption is consistent with empirical evidence about internal labour migration in Germany and elsewhere (see e.g., Hunt 2006). Also there is an exogenous fixed housing stock $\overline{B}_c$ that is owned by absentee landlords. High- and low-skilled labour is combined to produce a freely tradable, homogeneous final product under perfect competition. For simplicity I assume a simple Cobb-Douglas production function,

$$y_{j,c} = A_c \left(\ell_{j,c}\right)^{\alpha} \left(h_{j,c}\right)^{1-\alpha} \qquad 0 < \alpha < 1 \qquad (1)$$

where $y_{j,c}$ denotes production of firm j located in city c, $\ell_{j,c}$ is the input of low-skilled workers, and $h_{j,c}$ is the input of high-skilled workers in that firm. The price of this good is normalised to unity ($p_Y = 1$). The centripetal force in this model is a localised spillover effect that is introduced in a similar way as in Lucas (1988) or Moretti (2004a) by assuming that total factor productivity in city c, denoted A_c , depends endogenously on aggregate local human capital. In particular, I assume that it depends on the local human capital *intensity*

$$A_c = \varphi_c \left(\frac{H_c}{L_c} \right)^{\gamma} \tag{2}$$

$\varphi_c > 0$ is some exogenous and city-specific productivity parameter, and $\gamma \geq 0$ measures the strength of the localised externality. Individual firms, whose subscript j will be dropped from now on, take the productivity level as given.[4] With perfectly competitive labour markets, the wages paid to low-skilled and high-skilled workers by a typical firm are given by

$$w_c^L = \alpha \cdot \varphi_c \cdot \left(H_c / L_c \right)^{1-\alpha+\gamma} \tag{3}$$

$$w_c^H = (1-\alpha) \cdot \varphi_c \cdot \left(H_c / L_c \right)^{\gamma-\alpha} \tag{4}$$

Assume that the population of low-skilled workers in city c is exogenous and given by $\bar{L}_c$. Let (inverse) low-skilled labour supply be described by the function $w_c^L = \left(L_c^S \right)^{\varepsilon}$, where $\varepsilon > 0$ is the constant supply elasticity. Equilibrium employment of low-skilled workers can then be expressed in terms of high-skilled employment in city c,

$$L_c = \left(\alpha \cdot \varphi_c \right)^{1/(1-\alpha+\gamma+\varepsilon)} \cdot \left(H_c \right)^{\psi} \qquad \psi \equiv \frac{1-\alpha+\gamma}{1-\alpha+\gamma+\varepsilon} \in [0,1] \tag{5}$$

The parameter ψ ranges between zero and one, and it increases with the strength of the externality (γ). Eqs. (3) and (5) show that the wage, and the employment level of low-skilled workers both depend positively on the level of human capital employed in city c, even in the absence of any externality (i.e., $\partial w_c^L / \partial H_c > 0$ and $\partial L_c / \partial H_c > 0$ even with $\gamma = 0$). This arises purely because the two types of labour are imperfect substitutes in production, i.e., because of the positive cross-partial derivative of the production function (1). With a positive human capital externality, w_c^L and L_c are both higher the larger is γ. Substituting (5) into (4), I derive the equilibrium wage of high-skilled workers as

[4] Note that the particular functional forms are chosen purely for analytical simplicity. The main qualitative results would also arise with a different constant-returns production function (e.g., CES), or with a different specification of the externality. E.g., in Lucas (1988) productivity A_c is assumed to depend on the local human capital *share*. This would considerably complicate the math in my model, however.

$$w_c^H = \left[(1-\alpha) \cdot (\alpha)^{\frac{\alpha-\gamma}{1-\alpha+\gamma+\varepsilon}} (\varphi_c)^{\frac{1+\varepsilon}{1-\alpha+\gamma+\varepsilon}} \right] \cdot (H_c)^{(1-\psi)(\gamma-\alpha)}, \quad (6)$$

and the following result is then readily verified:

Proposition 1: *The equilibrium wage of high-skilled workers in city c, w_c^H, is increasing (decreasing) in the local employment of human capital, H_c, if γ is larger (smaller) than α. The wage w_c^H does not depend on H_c if $\gamma = \alpha$.*

If the externality is absent or weak, the model conveys the straightforward neoclassical message that the wage for high-skilled workers should be lower in human capital abundant areas. This neoclassical supply effect is only offset if the externality is sufficiently strong, namely if $\gamma > \alpha$, so that there are localised increasing returns to human capital.[5]

The present paper is mainly concerned with the long-run consequences of human capital externalities for the spatial evolution of human capital. To this end, I need to move from equilibrium (nominal) wages to the equilibrium location choice of mobile high-skilled workers. Suppose individuals have preferences defined over housing and the tradable consumption good. Preferences are described by the following quasi-linear utility function

$$U_{i,c} = Y_{i,c} + \mu \cdot \log\left(B_{i,c}\right) \qquad \mu > 0 \quad (7)$$

where $U_{i,c}$ is the utility level of individual *i* living in city *c*. The elimination of income effects from housing demand makes sure that all individuals purchase the same lot size (μ / p_c), and that indirect utility of a high-skilled worker living in city c can be written as

$$V_c^H = w_c^H - \mu \cdot \log(p_c) + \mu\left[\log(\mu) - 1\right] \quad (8)$$

[5] The proposition is helpful to illustrates the main result by Moretti (2004a). Applying a similar framework on US individual earnings data while controlling for unobserved ability he finds that $\partial w_c^H / \partial H_c > 0$. In terms of the model presented here this suggests that $\gamma > \alpha$ in the US. Note, however, that $\partial w_c^H / \partial H_c > 0$ is sufficient, but not necessary for the existence of an externality. With $0 < \gamma < \alpha$ an externality exists, but it is not sufficiently strong to render localised increasing returns to human capital.

p_c is the housing price in that location.[6] The housing market is assumed to be competitive, i.e. the housing price adjusts so as to equate supply and demand, hence

$$p_c = \mu\left[\bar{L}_c + H_c\right]/\bar{B}_c \tag{9}$$

From eq. (9) and the assumed exogeneity of the housing stock $\bar{B}_c$ and the low-skilled population $\bar{L}_c$, it is easy to see that the housing price in city c is increasing as more high-skilled workers move in ($\partial p_c/\partial H_c > 0$). Using (6), (8) and (9) indirect utility of a high-skilled worker in city c can be written as

$$V_c^H = \tilde{\varphi}_c \cdot \left(H_c\right)^{(1-\psi)(\gamma-\alpha)} - \mu \cdot \log\left(\bar{L}_c + H_c\right) + \mu \cdot \log\left(\bar{B}_c\right) + \mu\left[\log\left(\mu\right) - 1\right] \tag{10}$$

where $\tilde{\varphi}_c \equiv (1-\alpha)\cdot\alpha^{\frac{\alpha-\gamma}{1-\alpha+\gamma+\varepsilon}}\left(\varphi_c\right)^{\frac{1+\varepsilon}{1-\alpha+\gamma+\varepsilon)}} > 0$. This equation shows that utility V_c^H depends *positively* on H_c if and only if the strength of the externality (the centripetal force) is *sufficiently* strong to compensate both centrifugal forces, the neoclassical supply and the housing scarcity effect ($\partial V_c^H/\partial H_c > 0 \;\Leftrightarrow\; \gamma \gg \alpha$).

In a long-run spatial equilibrium high-skilled workers must be indifferent in which city to locate. That is, for each pair of cities k and m it must be true that (indirect) utility is equalised,

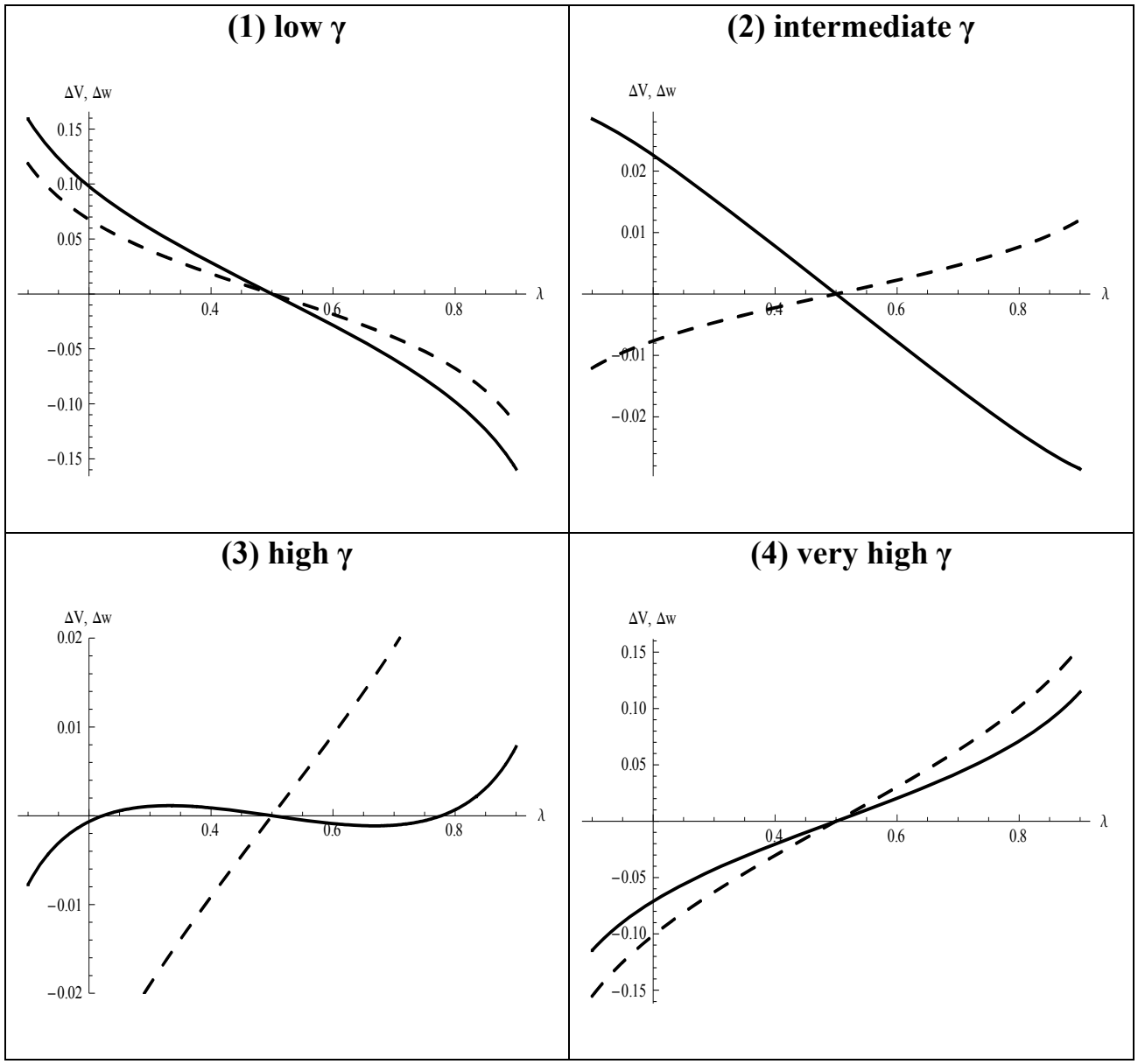
$$V_k^H - V_m^H = \left[w_k^H - w_m^H\right] - \mu \cdot \log\left(p_k/p_m\right) = 0 \qquad \forall k,m \in \{1,...,N\} \tag{11}$$

The consequences of this spatial equilibrium concept are most easily illustrated for the case of two identical cities with identical low-skilled population, housing stock and productivity level φ_c. In this case, equal distribution of high-skilled workers across the two cities ($H_1 = H_2 = H$) must be an equilibrium. However, depending on the strength of the human capital externality, this symmetrical equilibrium need not be stable. In figure 1 I have plotted the the utility differential (the solid line) and the nominal wage differential (the broken line) for high-skilled

[6] I have ruled out city-specific consumption amenities that potentially could also depend endogenously on the local level of human capital (see Shapiro, 2006). This simplification is justified, because below I report evidence that is consistent with a production externality of human capital, but not with a consumption externality.

workers, against the share of high-skilled workers located in region 1. I have used common values for the exogenous parameters in both cities, and I look at four different scenarios which only differ by the strength of the human capital externality γ.

Figure 1: Spillover strength and spatial equilibrium with two identical cities



If the strength of the externality is weak or zero, equal distribution of high-skilled workers is the only equilibrium, which is also stable (panel 1). Hence, starting off from any initial distribution of human capital across space we would expect to see a convergence of local human capital shares. Note that the slope of the utility differential is stronger negative,

because it entails both centrifugal forces, whereas the nominal wage differential only captures the neoclassical supply effect but not the housing congestion. In panel (2) the centripetal force is strong enough to render higher nominal wages for high-skilled workers in human capital abundant areas, but not strong enough to render divergence. The localised increasing returns are too weak to offset the housing congestion force in this case. Increasing γ even further leads to a small parameter range where the model exhibits multiple equilibria: a locally stable equilibrium with equal distribution of high-skilled workers, accompanied by two unstable equilibria with partial agglomeration of high-skilled workers (panel 3). Finally, in panel 4 the centripetal force is so strong that it generates global human capital divergence, i.e., complete concentration of all high-skilled workers in a single region.

To sum up, the small theoretical model predicts that in the absence of a localised a human capital externality we would expect to observe convergence of human capital shares across space by standard neoclassical mechanisms. The reverse, however, is not true. Convergence is consistent with localised increasing returns to human capital ($\gamma > \alpha$, see panel 2). The observation of local human capital *divergence* (panel 4) would be an empirical indicator for a *strong* local concentration force that offsets several opposing centrifugal forces.

Before turning to the empirical part of this paper, I shall put the theoretical framework into a broader perspective. I have presented a static model where agglomeration is driven by geographical mobility of high-skilled workers, and where the agglomeration force is specified in an ad-hoc way. This simple model could be changed or extended in various directions, presumably without affecting its main qualitative insights. Suppose, firstly, that all workers were geographically immobile (which would be an extreme representation of the lower mobility of Europeans), but that qualification decisions are endogenous. Without human capital externalities, the relative wage of high-skilled workers, and thus the incentive to become skilled, would be highest in those regions where human capital is initially relatively

scarce. Hence, we would expect a convergence of local human capital shares through education choices even in the absence of any labour mobility.

Secondly, the model is static even though the empirical analysis below will look at local employment growth and is therefore more "dynamic". However, the static setup is mainly for analytical simplicity. A dynamic version is conceivable, e.g. by assuming that the technology level φ_c grows at an exogenously given rate. With weak or zero spillovers, migration takes place to equalise relative factor shares, so that regions converge to the balanced growth path. With sufficiently strong externalities, one region would gradually be abandoned by high-skilled workers. Furthermore, the static model still yields some sensible predictions even for a dynamic empirical analysis if we interpret the empirical trends as movements towards a long-run equilibrium configuration. In the model a symmetrical equilibrium always exists, but in the case of a shock the economy may move towards concentration. In reality such a trend takes time, so gradual divergence in the data would be consistent with the case in panel 4 of the static theoretical model. An alternative would be to assume that the economy is in its long-run spatial equilibrium, and that locations experience idiosyncratic random shocks. Again, without sufficiently strong externalities the system would not deliver concentration of high-skilled workers, but with strong externalities shocks may become self-reinforcing.

Finally, the intuition of the model does not hinge crucially on the specific agglomeration force. Several micro-foundations for concentration forces have been discussed in the literature (Duranton and Puga 2004), and similar conclusions as in the present model would follow with a different localised centripetal force that depends endogenously on human capital.

3) Data and descriptive overview

For this study I exploit two data sources. I mainly work with the official employment statistics provided by the Institute of Employment Research (IAB) of the German Federal Employment Agency. This highly reliable official information entails the complete population of full-time

employment relationships in Western Germany (excluding Berlin) subject to social security, i.e. without civil servants and self-employed individuals. Employment is observed annually from 1977 until 2006 on the spatial scale of 326 NUTS3-districts ("Landkreise" and "kreisfreie Städte"), referring to workplace location. For each local industry I can observe a number of structural characteristics of the workforces (such as industry, firm size, age and gender composition), and most importantly the employment shares of three different qualification groups: individuals without any vocational qualification (low-skilled workers), completed apprenticeship (medium-skilled workers), and completed tertiary education (high-skilled workers). The second data source is *Statistik Regional*, which is provided by the German Federal Statistical Office (StatBA). It entails information at the district level about regional GDP, residence population, area size in km^2, and land prices. Unfortunately it only covers the more recent time period 1995-2006.

The spatial unit of observation may be problematic. NUTS3-districts are small and administratively defined regions which are unlikely to be independent but spatially correlated amongst each other. To illustrate this, recall that we have assumed in the model that workers can only change locations by moving across regions. In reality, however, individuals may choose to commute across regions, which naturally generates some spatial dependence (see Hunt 2006 on commuting in Germany). Since Anselin (1988) it is known that the neglect of such spatial autocorrelation can lead to biased and inefficient estimates (also see Huger et al. 2008 and Kosfeld 2007). To address this concern I resort to spatial econometric techniques and estimate standard spatial lag and spatial error models. Furthermore, in another robustness check I also conduct my analysis on the level of 204 labour market areas ("travel to work areas", *Arbeitsmarktregionen*) which are defined by the IAB in order to minimise cross-regional commuting flows. Data for these spatial units of observations, between which spatial dependency is less likely to be a severe problem, are also only available to me from 1995 onwards. As it turns out, my main results are robust across these various specifications.

Figure 2 plots the development of total full-time employment in Western Germany (1977=1.00) and the respective development of full-time employment for high skilled workers only. Whereas the total number of full-time jobs has remained remarkably flat over the observation period, the number of high-skilled jobs has more than doubled over time. The average human capital employment share has increased from 3.7% in 1977 to 9.7% in 2006.

Figure 2: Total and high-skilled employment 1977-2006 (1977=1)

These aggregate numbers hide strong differences between individual regions. In table 1 (columns 1 and 2) I report the districts with the highest and with the lowest human capital employment share in 1977 and 2006. In column 3 I report the districts with the highest and the lowest long-run *growth rate* of the local human capital employment share. Human capital shares differ by a factor larger than 10 across districts. An established fact from the urban economics literature that can also be observed in Germany is that metropolitan areas (like Munich, Stuttgart, Frankfurt or Hamburg) exhibit large employment shares of high-skilled workers. Yet, medium sized and strongly specialised cities also tend to be highly skilled. In

fact, the "smartest" German city in all years of observation has been Erlangen (with population size at around 100,000), where the headquarters of *Siemens* are located.

Table 1: Local employment shares of high-skilled workers

Rank	(1) **Human capital share 1977**		(2) **Human capital share 2006**		(3) **Growth of local human capital share** (1977-2006)	
	District	**%**	**District**	**%**	**District**	%
1	Erlangen	15.7	Erlangen	25.6	Ingolstadt	526.1
2	Outer-Munich	11.0	Inner-Munich	21.5	Wolfsburg	487.8
3	Darmstadt	9.1	Darmstadt	21.3	Rhein-Neckar-Kreis	484.6
4	Frankfurt a.M.	8.2	Stuttgart	21.1	Aschaffenburg	486.1
5	Inner-Munich	8.1	Outer-Munich	20.8	Heilbronn	409.6
…	…	…	…	…	…	…
322	Cochem-Zell	0.9	Freyung-Grafenau	2.9	Ludwighafen	77.8
323	Regensburg	0.9	Straubing-Bogen	2.8	Cuxhaven	73.7
324	Neustadt a.d.W.	0.8	Regen	2.8	Frankenthal (Pfalz)	60.2
325	Wolfsburg	0.7	Bamberg	2.8	Erlangen	55.9
326	Südwestpfalz	0.6	Ansbach	2.7	Herne	13.4

Turning to growth of the local human capital share, column 3 shows that even the worst performing city, Herne in the Ruhr area, has experienced a *positive* growth rate of 13.4%. This implies that the high-skilled employment share has increased in *each* Western German district between 1977 and 2006. But table 1 also suggests that initial level and long-run growth of local human capital shares are negatively correlated. For example, Wolfsburg has one of the highest *growth rates* but also one of lowest *initial levels* of the local human capital share. The opposite is true for Erlangen which belongs to the group with the highest initial level but with the lowest growth rate. The impression of a negative correlation is further corroborated in figure 3. In a univariate OLS regression linking the (log) initial level with the long-run growth rate of the local human capital shares I estimate a coefficient of –0.130 (std. error 0.17) as indicated by the negatively sloped line. Given this initial evidence for "β-convergence" one should check if there also has been "σ-convergence" over time (see

Magrini 2004 for the different concepts of convergence). Figure 4 illustrates the coefficient of variation based on the weighted standard deviation. There has been, in fact, a steady decline in cross-district dispersion of local human capital shares ("σ-convergence").

Figure 3: Initial level and long-run growth rate of local human capital shares (N=326)

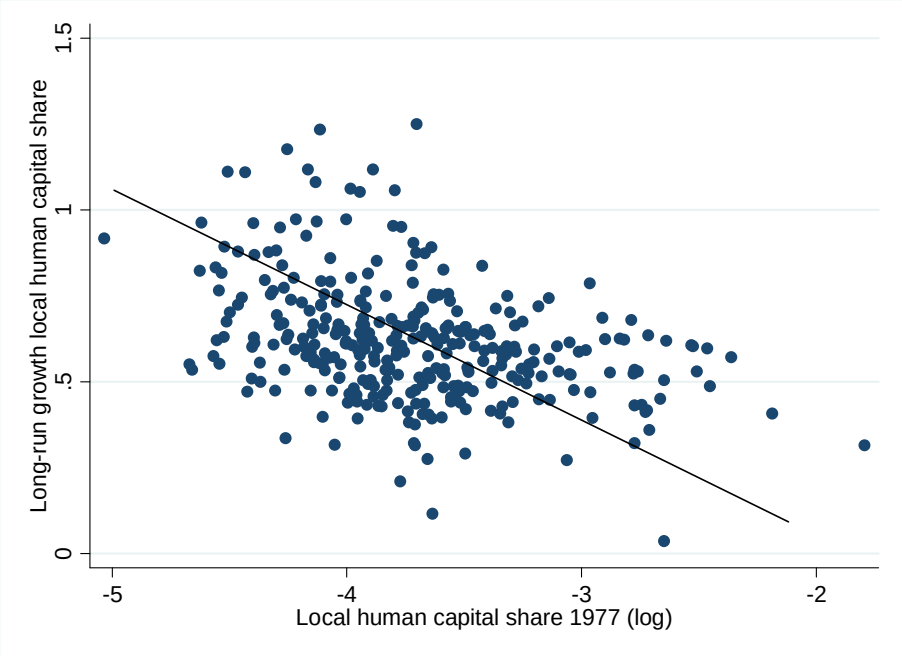
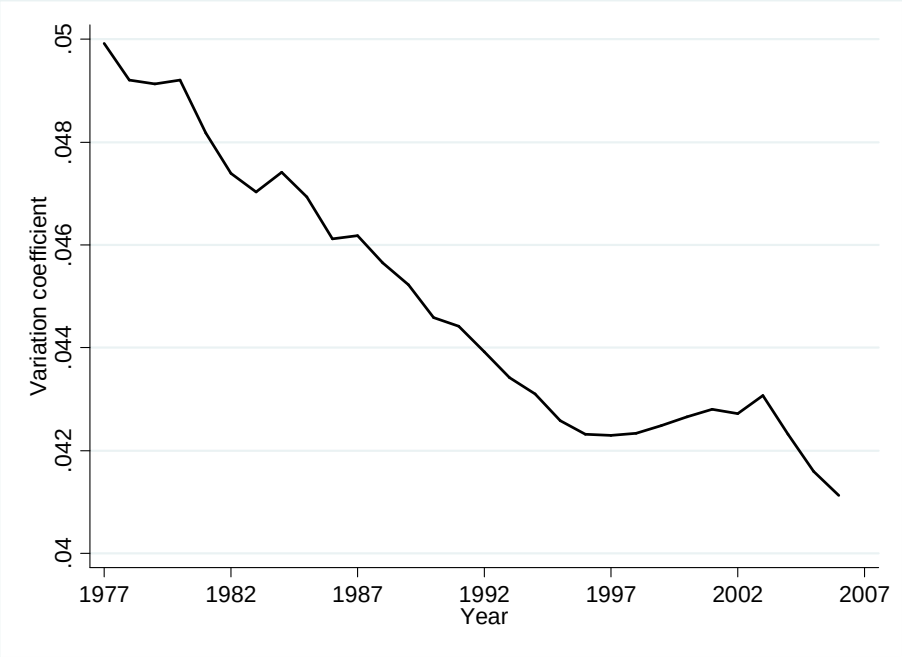


Figure 4: Variation coefficient of local human capital shares 1977-2006 (N=326)



Together with the general tendency of all cities to become more skilled over time, figures 3 and 4 therefore suggest that high-skilled employment grew over-proportionally in districts with a relatively small initial human capital share. This conclusion will be verified in the statistical analysis to which I turn now.

4) Empirical specification and results

I start with a cross-sectional approach to investigate the impact of local human capital on total and qualification-specific employment growth rates (section 4.1). In section 4.2 I turn to (static and dynamic) panel estimations of local employment growth. Finally, in section 4.3 I utilise the *Statistik Regional* data to provide results on the impact of human capital on regional productivity, wages, and land prices.

4.1. Regional employment growth: A cross-sectional analysis

To test the "smart city hypothesis" in the most basic way, I regress long-run growth rates of total employment on local base year characteristics. I then exchange the dependent variable with the growth rate of high-skilled (low-skilled) jobs. Growth rates in this benchmark specification are computed for the period 1985-2006, but to avoid issues of reverse causality I use all control variables for the year 1977.[7] The central explanatory variable is the initial employment share of high-skilled workers in city c in 1977. As additional natural controls I use the employment share of medium-skilled workers, employment density (total employment over area size in km^2), local industry and firm size composition, as well as the age and gender structure of the local workforces.

Table 3 (left column) reports the results of the benchmark OLS regression with robust standard errors. The impact of the initial employment share of high-skilled workers on total

[7] It seems implausible to argue that skilled workers have moved to a particular city in 1977 because they expected growth to be strong from 1985 onwards. We have experimented with different time periods for growth rates. To avoid outlier problems for single years we have also computed growth rates by using three year averages for the base and the end period. The results were very similar to those reported here.

employment growth is significantly positive, see specification 1a. The initial share of medium-skilled employees also significantly raises total city employment growth, but the impact is considerably smaller. The other estimated coefficients have the expected signs and are (with the exception of the age-related variables) statistically significant.

This simple regression already conveys an important message: There seems to be an independent impact of human capital on local employment growth that is robust to including many further controls such as the regional industry composition. This impact, in fact, appears to be quite large. An increase of the employment share of high-skilled workers by one percentage point raises total local employment growth by roughly 2.4 per cent. Glaeser and Saiz (2004), who also use a log-linear specification and regress population growth of US metropolitan areas on the initial population share of inhabitants with (at least) a Bachelor's degree obtain coefficients that are considerably smaller (between 0.2 and 0.5 in regressions without local fixed effects). One important reason for this quantitative difference supposedly is the definition of what is a "high-skilled worker". For Germany this group consists of university graduates, who have obtained a Diploma or a comparable degree, which is actually closer to a Master's than to a Bachelor's. The group of medium-skilled workers has completed the German system of vocational training (*Facharbeiter*). As the post-secondary education for this group usually exceeds three years, this group might also be regarded as skilled workers. When university graduates and medium-skilled workers are lumped together in one skill group I obtain a coefficient of 0.3625** (t-value 2.44) when redoing the estimation 1a, which is nicely in line with the findings of Glaeser and Saiz (2004).

TABLE 3 HERE

In the specifications 1b-1d the dependent variable is the long-run growth rate of local low-skilled, low- and medium-skilled, and high-skilled employment, respectively. The central

finding can be summarised as follows: Whereas the initial share of high-skilled workers in a city significantly raises subsequent growth of low-skilled jobs (and to a lesser extent of medium-skilled jobs), it significantly reduces growth of high-skilled jobs. The estimated coefficient for the impact on low-skilled employment (4.778) is more than twice as large as the coefficient for total employment (1.827), whereas the impact on high-skilled employment growth (-2.576) is decisively negative.

The OLS estimation presented in column 1 does not take into account spatial dependency across the single units. When computing the standard Moran's I statistic for the regional human capital shares, I receive highly significant values of 0.22 for 1977 and 0.32 for 2006, respectively, which suggests that the OLS estimation is plagued by spatial autocorrelation (see Anselin 1988).[8] To address this issue I therefore estimate a spatial error (column 2) and a spatial lag (column 3) model of the same specification as in column 1. As indicated by the results in table 3, however, it turns out that my main results remain robust.

Thus, summing up, the cross-sectional analysis suggests that "skilled" German region have exhibited faster employment growth than "unskilled" German cities, but this is driven by a strongly positive impact on low-skilled employment growth. High-skilled employment growth is lower in human capital intensive regions, which is consistent with a convergence of the skill composition across the German regions.

4.2. Panel analysis

Even though the cross-sectional analysis has controlled for various characteristics of the local workforces there is still the potential problem that human capital may proxy for unobserved local characteristics that drive employment growth. For example, some districts are located in more pleasant environments than others, or offer more attractive productive amenities, which

[8] To compute Moran's I and to estimate the spatial lag and error model I make use of a simple spatial contiguity matrix as the spatial weight matrix W. In the present context this is a simple 326×326 matrix with value 1 if two regions are directly adjacent to each other and value 0 otherwise.

in turn may affect employment growth. To address this issue, I make use of the longitudinal data structure and turn to panel estimation. In this section I will consider two different specifications of a regional panel model. The first one is a standard static panel model that includes regional fixed effects.[9] This within-estimator controls for those unobservable local characteristics that do not vary over time. The second specification is a dynamic panel estimation á la Arrelano and Bond (1991). With this approach I specifically address the relevant timing of the effects, and I discuss possible endogeneity concerns.

4.2.1. Static panel model

For the static panel analysis I construct annual employment growth rates, which I regress on time-lagged local characteristics. The estimation equation is given by

$$\mathbf{log}\left(\frac{emp_{c,t}}{emp_{c,t-1}}\right) = \alpha + \mu_c + \lambda_t + \beta X_{c,t-1} + \varepsilon_{c,t} \ ,$$

where emp_c is either total or qualification-specific employment in city c. λ_t is a time fixed effect and μ_c is a regional fixed effect. In table 4 I present the results. For brevity I concentrate on the central coefficient of interest. The set of control variables ($X_{c,t-1}$) includes all characteristics that are reported above in table 3, but the estimated coefficients are omitted.

The first line refers to the estimations where I use the 326 Western German districts (NUTS3) over the entire observation period from 1977-2006. All qualitative conclusions from the cross-sectional analysis remain valid: The human capital share is positively related to growth of low-skilled jobs (0.493), but negatively related to growth of high-skilled jobs (-0.751). The impact on total employment growth is also significantly positive (0.135) but smaller than in the regressions where we only look at growth of low- or low- and medium skilled jobs. The results in the second line pertain only to the post-reunification period from 1995-2006, which

[9] Including a fixed effect for every district is the strictest formulation of the fixed-effects model. Glaeser and Saiz (2004) argue that this approach is "asking a great deal from the data", because identification then comes from the change in the high-skilled employment share within a district over time. In other words, local fixed effects eliminate most of the variation due to the high persistence of human capital levels over time.

corresponds to the observation period of the secondary data source (*Statistik Regional*) that is used below. A similar picture emerges. The impact of the local human capital share on high-skilled job growth is even stronger negative in this more recent period, while we still find positive effects on low-, low- and medium-skilled and on total local employment growth.

Table 4: Human capital share and qualification specific employment growth - Panel analysis with regional fixed effects

	(1)	(2)	(3)	(4)
	Total empl. growth	**Low-skilled empl. growth**	**Low- + medium skilled empl. growth**	**High-skilled empl. growth**
NUTS3, 1977-2006 NOBS = 9454	**0.135***** (.032)	**0.493***** (.059)	**0.168***** (.033)	**-0.751***** (.073)
	R^2=0.67	R^2=0.76	R^2=0.68	R^2=0.42
NUTS3, 1995-2006 NOBS = 3912	**0.203***** (.071)	**1.282***** (.137)	**0.420***** (.072)	**-2.856***** (.017)
	R^2=0.84	R^2=0.89	R^2=0.85	R^2=0.64
Labour market areas, 1995-2006 NOBS = 2244	**0.170*** (.099)	**0.937***** (.197)	**0.273***** (.097)	**-2.718***** (.023)
	R^2=0.90	R^2=0.93	R^2=0.73	R^2=0.76
Other controls	log(emp.density), empl.share medium-skilled workers, fraction of men, average age, (average age)^2, empl. share in large firms (>100), traditional manufacturing, modern manufacturing, advanced services, basic services, constant term.			
Local area fixed effects	YES	YES	YES	YES
Time period fixed effects	YES	YES	YES	YES

Estimation method in all specifications is the fixed-effects (within) estimator. Standard errors are reported in parentheses. Significance levels: ***) 1%, **) 5%, *) 10%. The reported R^2 levels refer to the within-R^2.

Finally, I have again checked the robustness of my results with respect to the geographical units of observation. This time I did not resort to spatial econometric techniques, but I made use of the different classification system where local labour market areas are defined in order to minimise cross-regional commuting flows.[10] With this new regional classification of 204 labour market areas per year, I also reduce the concerns of spatial dependency. As can be seen

[10] There are some recent advances in the spatial econometric literature to address spatial autocorrelation in panel estimations, see Kapoor et al. (2007), Mutl and Pfaffermayr (2008), and Hujer et al. (2008). In this paper I use a simpler approach by working with a data set where spatial dependency is less likely to matter.

in the third line, the estimation results do not change qualitatively which is again suggestive that my findings are no artefacts of the spatial units.

Quantitatively, the inclusion of fixed effects works in the expected direction. In pooled cross-section regressions without regional fixed effects (not reported) I receive smaller but still significant negative effects of the local human capital shares on high-skilled employment growth. Idiosyncratic city effects positively covary with human capital. Not taking into account that certain locations constantly attract high-skilled workers leads to an understatement of the equilibrating forces for local human capital shares.

4.2.2. Dynamic panel model

Finally I conduct some dynamic panel estimation. As the dependent variable I specify the log human capital share in city c, $hc_{c,t}$, and estimate

$$\mathbf{log}\left(hc_{c,t}\right) = \mu_c + \lambda_t + \sum_{s=1}^{L}\left(\rho_s \cdot \mathbf{log}\left(hc_{c,t-s}\right) + \beta_s \cdot X_{c,t-s}\right) + \varepsilon_{c,t} \qquad (12)$$

where $X_{c,t}$ are the usual exogenous controls, μ_c are regional and λ_t are time period fixed effects. Of particular interest are the autoregressive coefficients ρ_s. If local human capital shares exhibit a convergence trend these coefficients should be well below unity. This would be inconsistent with the idea that local growth of human capital "feeds on itself". A divergence trend would instead be associated with autoregressive coefficients that exceed unity. The equation (12) above can be estimated by using OLS. As Nickell (1981) has shown, this would generate a bias in the presence of fixed effects due to the correlation of the lagged dependent variable with the error term. This so-called *dynamic panel bias* is particularly severe in panels with a short time dimension. Following Arellano and Bond (1991) one can then use the GMM method to get consistent estimates for the unknown coefficients.[11] Recall,

[11] The above equation is transformed into first differences, so that time-lagged dependent variables can be used as instruments (Anderson and Hsiao, 1982; Arellano and Bond, 1991). Crucial for their validity is the assumption about the order of autocorrelation of the error term. Under the assumption of serially uncorrelated $\varepsilon_{c,t}$,

however, that our panel for NUTS3 regions is unusually large in its time dimension (30 years) so that the dynamic panel bias can be expected to be small (see Roodman 2008).

This can easily be verified. When estimating a simplified version of (12) without further controls $X_{c,t}$ and with a lag structure L=1, I receive an autoregressive coefficient $\rho = 0.879***$ (std.error 0.01) when using OLS with fixed effects, and $\rho = 0.883***$ (std.error 0.004) when using (one-step) Difference-GMM. Both specifications thus predict convergence of local human capital shares with a similar degree of inertia. This conclusion is consistent with the previous cross-sectional and static panel analyses and inconsistent with the idea of a global divergence trend of the geographical distribution of human capital.

It should be noted, however, that the GMM approach is plagued with the problem of "too many instruments" in this context (see Roodman 2007), precisely because of the long time dimension of my panel. Without further restrictions the estimation draws on 435 instrumental variables, which clearly overwhelms the underlying moment condition and leads to a very poor outcome of the Sargan test ($\chi^2(405)=1379.2$, P-value 0.000). This problem can be tackled by reducing the array of instrumental variables to lower order time lags. When using only second-order lags (which yields 84 instruments in total) I receive $\rho = 0.889***$ (std.error 0.003) and cannot reject the null of no second order autocorrelation ($z = 0.903$, P-value 0.36), but even in that case the Sargan test rejects the model ($\chi^2(54)=484.36$, P-value 0.000). Using the System-GMM estimator by Blundell and Bond (2000), which could be better suited given the value of ρ, leads to no improvement. Estimating this model with a level equation, using the time dummies as exogenous instruments, and restricting the array of GMM-type instruments to two lags (109 instruments in total) I receive $\rho = 0.960***$ (std.error 0.001). However, the Hansen test still performs poorly, both with one-step and with two-step estimation, probably because the required stationarity conditions of this estimator are not fulfilled over the long time horizon of my panel.

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the first differenced error terms $\varepsilon_{c,t}$-$\varepsilon_{c,t-1}$ follow a MA(1) process, so $emp_{c,t-s}$ (s=2,3,…) are valid instruments for $\Delta emp_{c,t-1}$.

In the remainder of this section I will therefore estimate the dynamic panel model (12) simply with OLS instead of GMM, as the former is unlikely to generate a substantial bias in my case while the latter may yield unreliable estimates due to the improper instrumentation. In table 5 I report the results for the autoregressive coefficients of an extended model that differs in two respects from the above mentioned benchmark specification. Firstly, I again include all the usual regional control variables $X_{c,t}$ in order to avoid omitted variable bias (though I do again not report the estimated coefficients for brevity). Secondly, I assume a richer lag structure with L=3 lags for the dependent and the independent variables.[12] This specification is useful for addressing the relevant timing of the impact of human capital.

Table 5: Dynamic panel analysis (1977-2006)

	ρ_{-1}	ρ_{-2}	ρ_{-3}
$\log(hc_{t-s})$	**0.713***** (.029)	**0.071***** (.013)	0.026 (.044)
	R^2 (within) = 0.98		
Other controls (with L=3 lags)	log(emp.density), empl.share medium-skilled workers, fraction of men, average age, (average age)^2, empl. share in large firms (>100), traditional manufacturing, modern manufacturing, advanced services, basic services, constant term.		
Local area fixed effects	YES	YES	YES
Time period fixed effects	YES	YES	YES

Estimation method in all specifications is the fixed-effects (within) estimator. Standard errors are reported in parentheses. Significance levels: ***) 1%, **) 5%, *) 10%. The reported R^2 levels refer to the within-R^2.

As can be seen, the impact of the lagged dependent variables remains decisively below unity. In fact, the autoregressive coefficients tend to decrease in absolute terms when including the further regional control variables. This corroborates again the insight that there is no divergent path of local human capital shares in Germany. Second, the impact of human capital dies out quickly over time. The coefficients of higher-order time lags are far smaller than ρ_{-1}, and there are no significant effects for s>2. It seems to be the current rather than some lagged

[12] I could also include further time lags, but this would only lead to insignificant coefficients for the higher-order lagged dependent variables.

human capital share that influences local high-skilled growth performances.[13] All in all, this dynamic panel estimation confirms the insights from the more conventional static analysis: There is convergence, not divergence of local human capital shares in Western Germany.

4.3. Wages, productivity and land prices

One robust result that emerges from the analysis is that "skilled cities" exhibit stronger overall employment growth. Shapiro (2006) argues that there are two principal reasons for this finding. The first is that educated cities generate positive consumption externalities, or higher quality of life (e.g., via better designed local institutions), and thereby attract more individuals. An alternative theory postulates that human capital raises local productivity.

Building on a dynamic version of the spatial equilibrium concept by Roback (1982), Shapiro (2006) shows that land price and wage regressions can be used to discriminate between these two theories. Consumption amenities capitalise in local land prices, whereas local wages would be unaffected. If productivity is the main channel, wages should react stronger to human capital than land or housing prices (see Shapiro 2006 or Glaeser and Saiz 2004). Both papers agree that, even though consumption amenities also play some role, productivity appears to be the main reason for higher growth of skilled cities in the US. The theoretical model presented in section 2 also attributes the main role to production externalities and neglects consumption amenities.

In this subsection I briefly study the impact of human capital on average wages, land prices and labour productivity of Western German districts. I do not use individual earnings data in this study. Hence, I cannot disentangle disparities in the private returns to human capital.[14] I

[13] Estimating the specification in table 5 with one-step or two-step Differece- or System-GMM (two-step estimation with Windmeijer-corrected standard errors) yields similar results for the autoregressive coefficients. Specification tests cannot reject the null of no second order autocorrelation, but for the reasons explained above the Sargan or, respectively, the Hansen tests typically fail.

[14] Related works have often utilised Mincerian wage regressions and studied returns to education across regions. Shapiro (2006) has adopted a similar approach, and then studied the impact of the local human capital share on the regional fixed effects that were computed from the individual earnings regression. In this paper we can not

rely on the static panel setup and I use the *Statistik Regional* data described above, which covers the time period from 1995 to 2006. I use an estimation equation of the following form

$$\mathbf{log}\left(y_{c,t}\right) = \alpha + \mu_c + \lambda_t + \beta_1 \cdot \mathbf{log}\left(hc_{c,t-1}\right) + \beta_2 X_{c,t-1} + \varepsilon_{c,t} \ ,$$

where the dependent variable $y_{c,t}$ is either the average city wage, land price, GDP per capita of the residence population, or average labour productivity (GDP/total employment). I control for the time-lagged human capital share $hc_{c,t-1}$, the local population density (in logs), the other exogenous city features ($X_{c,t-1}$) that have been used above, as well as for time and regional fixed effects.

Table 6: Human capital and local wages, land prices and productivity – panel analysis with regional fixed effects, 1995-2006

	(1)	(2)	(3)	(4)
	Average wages	**Av. labour productivity**	**GDP per capita**	**Land price**
Log(high-skilled employment share$_{t-1}$)	**1.144***** (.039)	**0.991***** (0.72)	**0.606***** (.167)	0.394 (1.06)
Log(population density$_{t-1}$)	-0.004 (.011)	-0.029 (.047)	-0.067 (.047)	**0.749**** (.309)
Other controls	empl.share medium-skilled workers, fraction of men, average age, (average age)^2, empl. share in large firms (>100), traditional manufacturing, modern manufacturing, advanced services, basic services, constant term.			
Local area fixed effects	YES	YES	YES	YES
Time period fixed effects	YES	YES	YES	YES
R^2 (within)	0.97	0.61	0.71	0.15

Table 6 provides the results, which can be summarised as follows: The local human capital share in city c is significantly positively related to average labour productivity, wages and GDP per capita, but unrelated to land prices. Local land prices in Germany are measured with substantial error, which explains the low R^2 in the respective regression. An important insight

construct such a "neutralised" regional wage measure, but we use raw average city wage/productivity as the dependent variable.

that emerges from this exercise is that land prices are mainly determined by population density, but are not affected by the skill composition of the local workforce. In estimations without local fixed effects I generally obtain a significantly positive impact of the human capital share on land prices, but this does not seem to be a robust result. Once I control for time-invariant features that undoubtedly play an important role on local land markets, the positive impact of the human capital share vanishes.

In sum, these findings suggest that the human capital share has a positive impact on aggregate productivity at the local level, because the effect of human capital on GDP related productivity measures and on wages is significantly positive. This finding does not directly indicate that there are strong localised increasing returns to human capital, however. I can only conclude that there seems to be no evidence for a consumption value of the local human capital share that would capitalise in local land prices. The positive effect on productivity can in principle be due to different theoretical channels, externalities and imperfect substitutability (complementarity) of input factors, and the previous employment growth regressions from sections 4.1 and 4.2 suggest that the latter channel seems to be the more important one in the case of Western Germany.

5. Summing up and interpreting the evidence

In Western Germany skilled cities have grown stronger than unskilled ones. But this observed positive relation should not be hastily interpreted as evidence for a localised human capital externality. A large initial share of highly skilled workers significantly reduces subsequent growth of high-skilled jobs. Hence, the observed positive impact on total employment growth is due to the fact that the positive effect on low- and medium-skilled jobs outweighs the negative effect on high-skilled employment. This evidence is in line with complementarities among skill groups as the major causal link between human capital and regional employment growth. It does not reject human capital externalities, but it challenges “Silicon Valley-type”

theories of self-reinforcing spatial concentration of high-skilled workers due to localised external effects that are so strong to overturn countervailing dispersion forces.

My study points at some major differences between Western Germany and the US when it comes to the spatial evolution of human capital. It should be mentioned that only few papers have analysed the trends of the development of human capital across cities. These papers, namely Moretti (2004b), Berry and Glaeser (2005) and Wheeler (2006), interestingly find human capital divergence in the US (cif. footnote 3). In common with Suedekum (2008) I find that this development has been quite different in Western Germany, but in this paper I not only provide more detailed empirical results but also offer a theoretical interpretation by making use of a simple model.

In an aggregate sense, the stylised facts for the German economy suggest that concentration forces for human capital are not sufficiently strong to generate a self-reinforcing spatial clustering of high-skilled workers. As argued above, this does *not* imply, however, that agglomeration effects are absent in Germany. The findings by Moeller and Haas (2003) which are based on individual earnings data suggest that an agglomeration wage premium exists in Germany as well. This may be interpreted as indirect evidence for the existence of localised increasing returns to human capital. But this effect is apparently not sufficiently strong in Western Germany. The empirical findings by Berry/Glaeser (2005) and Wheeler (2006) is instead consistent with such a strong concentration force for high-skilled workers in the US. The evidence presented in this paper suggests that different countries exhibit different spatial trends in the distribution of human capital.

Several questions arise: *Why* are the concentration forces too weak in Germany to trigger spatial clustering of high-skilled workers? W*hy* has there been convergence of human capital shares across cities in Western Germany but divergence in the US? *How* does the evidence look like in other countries, i.e. which development is the exception and which is the rule? It is surely difficult to judge what precisely can explain the observed difference between

Western Germany and the US. In the remainder I shall at least discuss two *potential* reasons that may play at least *some* role. Underlying these explanations is the presumption that there are no fundamental differences between the two countries that lead to different strengths of agglomeration and dispersion forces due to deep technological reasons. Human capital may still exhibit a different spatial trend, because the incentives for high-skilled workers to be geographically mobile and to cluster in space may be lower.

- Taxes are higher, and the tax system is more progressive in Germany than in the US. Hence a larger part of the agglomeration wage premium that could be earned by a high-skilled worker when moving to a skilled city would be taxed away. This suggests that lowering taxes in Germany would foster human capital concentration in cities by increasing the incentives for earning a wage premium, and would lead to a development that is more in line with the US experience.

- Pro-dispersive regional policy plays a more important role in Germany. For example, after the 1970s there has been a considerable expansion in tertiary education in Germany. New universities and colleges were set up, and they have been located over-proportionally often in peripheral and remote regions. This political decision, coupled with the lower geographical mobility of German students before and after graduation (studying and working close to home), contributes to spatial convergence of local human capital shares.

This short list of explanations is by no means exhaustive. Different arguments like the role of overall country size and population density, or the impact of union wage setting may also be discussed. An in-depth evaluation of these or other theories is left for further research.

Literature

Acemoglu, D. (1996), A Microfoundation for Social Increasing Returns in Human Capital Accumulation, *Quarterly Journal of Economics* 111: 779-804

Anderson, T. and C. Hsiao (1982), Formulation and Estimation of Dynamic Models Using Panel Data, *Journal of Econometrics* 18: 47-82

Anselin, L. (1988) Spatial Econometrics: Methods and Models. Boston: Kluwer

Arellano, M., S. Bond (1991), Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *Review of Economic Studies* 58: 277-297

Audretsch, D. and M. Feldman (1996), R&D Spillovers and the Geography of Innovation and Production, *American Economic Review* 86, 630-640

Berry, C. and E. Glaeser (2005), The Divergence of Human Capital Levels across Cities, *Papers in Regional Science* 84: 407-444

Blundell, R. and S. Bond (2000), GMM Estimation with Persistent Panel Data: An Application to Production Functions, *Econometric Reviews* 19: 321–40

Ciccone, A. and G. Peri (2006), Identifying Human Capital Externalities: Theory with an Application to US cities, *Review of Economic Studies* 73: 381-412

Duranton, G. (2006), Human Capital Externalities in Cities: Identification and Policy Issues, in: Arnott, R. and D. McMillen (eds.), *A Companion to Urban Economics*, Blackwell

Duranton, G. and D. Puga (2004), Micro-Foundations of Urban Agglomeration Economies, in: Henderson, V. and J.-F. Thisse (eds.), *Handbook of Urban and Regional Economics*, Amsterdam: Elsevier-North Holland.

Glaeser, E. and A. Saiz (2004), The Rise of the Skilled City, *Brooking-Warton Papers on Urban Affairs* 5: 47-94

Glaeser, E., J. Scheinkman and A. Shleifer (1995), Economic Growth in a Cross-Section of Cities, *Journal of Monetary Economics* 36: 117-143

Henderson, V. (2003), The Urbanization Process and Economic Growth: The So-What Question, *Journal of Economic Growth* 8: 47-71

Hunt, J. (2006), Staunching Emigration from East Germany: Age and the Determinants of Migration, *Journal of the European Economic Association* 4: 1014-1037

Hujer, R., P. Rodrigues and K. Wolf (2008), Dynamic Panel Data Models with Spatial Correlation, *Jahrbücher für Nationalökonomie und Statistik* 228: 612-629

Kapoor, M., H. Kelejian, and I. Prucha (2007) Panel Data Models with Spatially Correlated Error Components, *Journal of Econometrics* 140: 97-130

Kosfeld, R. (2007), Regional Spillovers and Spatial Heterogeneity in Matching Workers and Employers in Germany, *Jahrbücher für Nationalökonomie und Statistik* 227: 236-253

Lucas, R. (1988), On the Mechanics of Economic Development, *Journal of Monetary Economics* 22: 3-42

Magrini, S. (2004), Regional (Di)Convergence, in: Henderson, V. and J.-F. Thisse (eds.), *Handbook of Urban and Regional Economics*, Amsterdam: Elsevier-North Holland.

Mankiw, G., D. Romer and D. Weil (1992), A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics* 107, 407-437

Marshall, A. (1890), *Principles of Economics*, London: MacMillan.

Moeller, J. and A. Haas (2003), The Agglomeration Wage Differential Reconsidered - An Investigation Using German Micro Data 1984-1997, in: Broecker, J., D. Dohse and R. Soltwedel (eds.), *Innovation Clusters and Interregional Competition*, Springer, pp. 182-217.

Moretti, E. (2004a), Estimating the Social Returns to Higher Education: Evidence from Longitudinal and Repeated Cross-Section Data, *Journal of Econometrics* 121: 175-212

Moretti, E. (2004b), Human Capital Externalities in Cities, in: Henderson, V. and J.-F. Thisse (eds.), *Handbook of Urban and Regional Economics*, Amsterdam: Elsevier-North Holland.

Mutl, J., and M. Pfaffermayr (2008) The Spatial Random Effects and the Spatial Fixed Effects Model: The Hausman Test in a Cliff and Ord Panel Model, Discussion Paper 229, Institute for Advanced Studies, Vienna

Nickell, S. (1981), Biases in Dynamic Models with Fixed Effects, *Econometrica* 49: 1417-1426

Rauch, J. (1993), Productivity Gains from Geographic Concentration of Human Capital: Evidence from the Cities, *Journal of Urban Economics* 34: 380-400

Roback, J. (1982), Wages, Rents, and the Quality of Life, *Journal of Political Economy* 90: 1257-1278

Roodman, D. (2007), A Short Note on the Theme of Too Many Instruments, Working paper 125, Center for Global Development, Washington

Roodman, D. (2008), How to Do xtabond2: An Introduction to "Difference" and "System" GMM in Stata, Working paper 103, Center for Global Development, Washington

Rosenthal, S. and W. Strange (2004), Evidence on the Nature and Source of Agglomeration Economies, in: Henderson, V. and J.-F. Thisse (eds.), *Handbook of Urban and Regional Economics*, Amsterdam: Elsevier-North Holland.

Shapiro, J. (2006), Smart Cities – Quality of Life, Productivity, and the Growth Effects of Human Capital, *Review of Economics and Statistics* 88: 324-335

Simon, C. (2004), Industrial Reallocation across US Cities 1977-1997, *Journal of Urban Economics* 56: 119-143

Simon, C. (1998), Human Capital and Metropolitan Employment Growth, *Journal of Urban Economics* 43: 223-243

Simon, C. and C. Nardinelli (2002), Human Capital and the Rise of American Cities 1900-1990, *Regional Science and Urban Economics* 32: 59-96

Suedekum, J. (2008), Convergence of the Skill Composition across German Regions, *Regional Science and Urban Economics* 38: 148-159.

Wheeler, C. (2006), Human Capital Growth in a Cross Section of US Metropolitan Areas, *Federal Reserve Bank of St. Louis Review* 88: 113-132

Table 3: Long-run analysis (N=326)

	(1) OLS				(2) Spatial Error				(3) Spatial Lag			
	Total Empl. 1a	**Low-Skilled 1b**	**Low+ Medium 1c**	**High-Skilled 1d**	**Total Empl. 2a**	**Low-Skilled 2b**	**Low+ Medium 2c**	**High-Skilled 2d**	**Total Empl. 3a**	**Low-Skilled 3b**	**Low+ Medium 3c**	**High-Skilled 3d**
High-skilled empl. share	**1.827**** (.93)	**4.778***** (1.37)	**1.435*** (0.79)	**-2.576**** (1.26)	**0.979*** (.55)	**3.651***** (.81)	**0.965**** (0.47)	**-3.817***** (1.09)	**1.606***** (.55)	**4.269***** (.83)	**1.415***** (0.48)	**-2.745***** (1.02)
Medium-skilled empl. share	0.355** (.17)	0.592** (.23)	0.235* (.14)	0.314 (.29)	0.269* (.14)	0.771*** (.24)	0.154 (.14)	0.032 (.32)	0.270* (.15)	0.554** (.23)	0.163 (.13)	0.199 (.28)
log(employment density)	-0.044*** (.01)	-0.011 (.02)	-0.046*** (.01)	-0.012 (.02)	-0.031*** (.01)	-0.035** (.02)	-0.038*** (.008)	-0.002 (.02)	-0.035*** (.01)	-0.009 (.01)	-0.040*** (.008)	-0.010 (.02)
Share of male employees	0.693*** (.20)	1.569*** (.28)	0.838*** (.17)	-0.278 (.32)	0.937*** (.18)	1.052*** (.27)	0.920*** (.16)	0.256 (.37)	0.755*** (.15)	1.245*** (.24)	0.861*** (.13)	-0.045 (.30)
Average age of employees	0.317 (.35)	0.524 (.55)	0.068 (.26)	0.742 (.70)	0.131 (.34)	-0.251 (.52)	0.007 (.30)	0.121 (.74)	0.259 (.35)	0.352 (.53)	0.075 (.31)	0.588 (.66)
(Average age of employees)^2	-0.005 (.004)	-0.007 (.01)	-0.001 (.01)	-0.011 (.009)	-0.002 (.004)	0.002 (.01)	-0.001 (.001)	-0.002 (.01)	-0.004 (.004)	-0.005 (.01)	-0.001 (.004)	-0.008 (.01)
employment share large firms (>100)	-0.469*** (.11)	-1.278*** (.18)	-0.520*** (.09)	-0.326 (.23)	-0.407*** (.11)	-0.958*** (.16)	-0.486*** (.09)	-0.340 (.10)	-0.466*** (.10)	-1.124*** (.16)	-0.521*** (.09)	-0.353* (.20)
traditional manufacturing	0.362*** (.12)	0.436** (.19)	0.460*** (.10)	0.744*** (.26)	0.177 (.12)	0.219 (.17)	0.333*** (.10)	0.481** (.24)	0.316*** (.11)	0.392** (.17)	0.424*** (.10)	0.645*** (.22)
modern manufacturing	0.714*** (.12)	0.676*** (.19)	0.674*** (.10)	1.031*** (.25)	0.443*** (.11)	0.397** (.17)	0.504*** (.10)	0.761*** (.23)	0.603*** (.11)	0.552*** (.17)	0.601*** (.09)	0.923*** (.21)
advanced services	0.871*** (.28)	0.876** (.40)	0.758*** (.24)	1.011* (.55)	0.649*** (.24)	0.369 (.36)	0.550** (.21)	0.856* (.47)	0.753*** (.25)	0.634* (.38)	0.648*** (.22)	0.925** (.47)
basic services	0.672*** (.23)	1.260*** (.35)	0.741*** (.21)	0.479 (.43)	0.436** (.20)	1.189*** (.29)	0.611*** (.17)	0.405 (.38)	0.496** (.20)	1.057*** (.31)	0.617*** (.18)	0.434 (.38)
Constant term	-5.224 (6.51)	-10.81 (10.26)	-1.191 (4.91)	-12.01 (13.1)	-1.669 (6.49)	4.146 (9.83)	0.122 (5.67)	-0.461 (13.83)	-4.337 (6.64)	-7.265 (9.96)	-1.370 (5.78)	-9.491 (12.30)
	R^2=0.55	R^2=0.46	R^2=0.58	R^2=0.32	λ=0.55 (0.00)	λ=0.56 (0.00)	λ=0.49 (0.00)	λ=0.35 (0.00)	ρ=0.34 (0.00)	ρ=0.31 (0.00)	ρ=0.27 (0.00)	ρ=0.18 (0.00)

Dep. variable in all regressions is the respective regional long-run employment growth rate (1985-2006). Control variables are for 1977. Robust standard errors are reported in parentheses. Significance levels: ***) 1%, **) 5%, *) 10%. Moran's I for regional high-skilled employment shares is 0.22 (P-value 0.000) for 1977 and 0.32 (P-value 0.000) for 2006. Model 1 assumes no spatial autocorrelation, models 2 and 3 account for spatial autocorrelation by means of the spatial error and the spatial lag model, respectively.