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

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ABSTRACT

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

In this paper I analyze the impact of human capital on local employment growth for the case of West Germany (1977-2002). I find robust evidence that skilled cities grow faster than unskilled ones, but this need not indicate localized human capital externalities are at work. A large initial share of high-skilled workers significantly reduces subsequent growth of high-skilled jobs. The observed positive impact on total employment growth is, therefore, due to the fact that low-skilled jobs grow faster than high-skilled jobs decline in initially skilled cities. This evidence is in line with complementarities among skill groups as the major causal link between human capital and employment growth. It challenges theories of self-reinforcing spatial concentration of high-skilled workers due to strong localized spillovers.

JEL Classification: R11, O40

Keywords: human capital, local employment growth, externalities

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1) Introduction

Previous research in urban economics has found a robust positive correlation between a city's initial 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.

Shapiro (2006) distinguishes three explanations. The first and most obvious one is omitted variable bias. Human capital may be correlated with other city characteristics that are left out of the regression, but which causally drive employment growth. One such feature may be the local industry structure. A city might strive not because it hosts a skilled body of employees, but because it is specialized in booming industries that use human capital intensively (Simon, 2004). Second, more educated cities might generate consumption amenities, or quality of life, thereby attracting more individuals subsequently (Shapiro, 2006). Finally, the positive correlation may be due to the fact that human capital raises local productivity. Glaeser and Saiz (2004) argue that productivity is probably the most relevant argument.

The literature has not yet come to grips, however, with the mechanism underlying the link between local human capital and productivity. Some recent papers that address the impact on local *wages* have put forward two explanations: externalities and imperfect substitutability of input factors. Total factor productivity may depend endogenously on the human capital share (as in Lucas, 1988), and the social returns exceed the private returns to education. This theory is underlying the seminal study by Rauch (1993), who finds that an increase in average schooling by one year at the city level increases wages of workers with unchanged education 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 effects (Krugman, 1991). However, human capital can raise wages above the private returns to education even in the absence of any spillover or market-mediated concentration force. It may simply reflect the imperfect substitutability of input factors that arises also in a straightforward neoclassical model with constant returns to scale and perfect competition. Policy implications crucially hinge on whether the observed positive relation is due to externalities or complementarities, because only the former are a standard source of market failure. In the literature that uses wages as the dependent variable, Moretti (2004a) and Ciccone and Peri (2006) have suggested strategies to discriminate between these two possibilities. Recent surveys are provided by Moretti (2004b) and Duranton (2004).

To the best of my knowledge there have been no attempts to disentangle whether complementarities or externalities are the main underlying cause for the link between human capital and local employment growth. This is the major goal of the present paper. Similar to the approach taken by Moretti (2004a), who looks at the impact of the local human capital share on wages of different education groups, I analyze its implications for subsequent local growth of high-skilled and low-skilled jobs. One would surely expect growth of low-skilled jobs in a city to depend positively on the initial share of high-skilled workers. This arises as a matter of complementarities between education groups alone, and is reinforced by external effects. With respect to high-skilled jobs, however, employment growth should be higher in cities where educated workers are initially relatively scarce – if not some human capital spillover, or some other local concentration force is countervailing this tendency. The effect of the initial human capital share on employment growth of high-skilled jobs is, therefore, used to discriminate between the two broad sets of theories.[1] Another contribution of this paper is that I provide novel evidence for another country, Germany (1977-2002), whereas the previous literature on education and employment growth has almost exclusively focused on US cities and metropolitan areas.[2]

I first report a robust positive impact of the initial employment share of high-skilled workers on subsequent *total* employment growth at the local level. Controlling for the city's industry and firm size structure changes the effect of human capital quantitatively, but not the general picture that skilled cities tend to grow faster on aggregate. These results corroborate earlier findings for the US, which suggests that European economies behave similarly in this respect. Differentiating between skill groups, I find that the initial human capital share is strongly positively related to subsequent growth of low-skilled jobs (as expected). For high-skilled employment growth, however, the effect is significantly and robustly negative. The positive impact on total employment growth is, therefore, due to the fact that low-skilled jobs grow faster than high-skilled jobs decline in initially skilled cities.

These empirical findings suggest the distribution of human capital across space should become more equal over time, and this impression is indeed verified by the data. The average national employment share of university graduates in Germany has strongly increased during the observation period (from 3.7 % in 1977 to 9.5% in 2002). But at the same time, regional human capital shares have tended to become more equal. This seems to contrast the recent US

[1] It is beyond the scope of this paper to differentiate between more detailed theories of human capital externalities (see Duranton and Puga, 2004 on this issue), or between a direct spillover and other potential concentration forces for high-skilled workers (like pecuniary externalities due to labor market pooling or endogenous market size effects).

[2] An exception is Simon and Nardinelli (1996), who look at growth of British cities between 1861 and 1961.

experience, because Moretti (2004b) points out that the distribution of human capital across MSAs have tended to become more unequal during the 1990s.

My results cast doubts on "Silicon valley-type" theories that imply a self-reinforcing spatial concentration of high-skilled workers due to strong localized human capital externalities. However, spillovers need not be absent completely. A first concern comes from the fact that I measure effects on employment growth, not on productivity directly. Human capital might stimulate technological progress at the local level, but this need not always translate into employment gains. Productivity growth can also be labor saving if goods demand is sufficiently inelastic, and the impact on employment is smaller the lower labor supply elasticity (Cingano and Schivardi, 2004; Combes et al., 2004). Unfortunately this concern can not be addressed in this paper, due to a lack of local productivity data. Second, even if productivity raises employment, my findings do not imply that spillovers are zero, but rather that (potential) spillovers are not strong enough to compensate a parallel "neoclassical" convergence tendency of local human capital shares.

Given this uncertainty if externalities are absent or only weak, I adopt an extended approach and look for evidence on potential cross-industry human capital spillovers. I move down from total city employment growth to the performance of different industries at the local level. For advanced service and modern manufacturing industries I find some evidence that is consistent with cross-industry spillovers, because high-skilled job growth is spurred by the local stock, and the degree of specialization of the surrounding human capital. Nonetheless, *within* these industries I still find a dominance of neoclassical convergence forces.

The rest of this paper is organised as follows. In section 2 I derive a simple theoretical model that guides the empirical research. Section 3 introduces the data set and provides a descriptive overview of human capital in German cities and industries. In section 4 I present the empirical specification, and the regression results for city employment growth. Section 5 turns to the growth performance of local industries. Some concluding remarks are provided in section 6.

2) Theory

The theoretical framework builds on Moretti (2004a) and serves to illustrate that the impact of initial human capital on subsequent *high-skilled* employment growth may be used to shed some light on the underlying causes of the link between human capital and total city employment growth. Suppose production of some homogenous and freely tradable good in city c (Y_c) is described by the following Cobb-Douglas function

$$Y_c = A_c \cdot (L_c)^{\alpha} \cdot (H_c)^{1-\alpha} \qquad 0 < a < 1 \tag{1}$$

where A_c is a city-specific productivity parameter, L_c is the factor input of low-skilled labor, and H_c is the input of high-skilled labor. There is perfect competition, so that the product price p_Y is taken as given by firms and normalized to one. Both input factors are paid according to their marginal product, which implies that

$$\log(w_c^L) = \log(\alpha) + \log(A_c) + (1-\alpha)\log\left(\frac{s_c}{1-s_c}\right) \tag{2}$$

$$\log(w_c^H) = \log(1-\alpha) + \log(A_c) - \alpha\log\left(\frac{s_c}{1-s_c}\right) \tag{3}$$

where $s_c = H_c/(L_c + H_c)$ is the city's share of high-skilled workers. I allow total factor productivity A_c to depend endogenously on s_c. In particular, I assume

$$\log(A_c) = \log(\varphi_c) + \gamma \cdot \log(1 + s_c) \tag{4}$$

where $\gamma \geq 0$ denotes the strength of the (potential) human capital externality, and φ_c is an idiosyncratic city effect that captures local amenities (like weather etc.). These characteristics may be correlated with local human capital (e.g., the skilled prefer to live in warm cities), which suggests that controlling for time-invariant city features may be important. Using (4) in (2) and (3), it is straightforward to compute that

$$\frac{\partial \log(w_c^L)}{\partial s_c} = \frac{1-\alpha}{s_c(1-s_c)} + \frac{\gamma}{1+s_c} \tag{5}$$

$$\frac{\partial \log(w_c^H)}{\partial s_c} = -\frac{\alpha}{s_c(1-s_c)} + \frac{\gamma}{1+s_c} \tag{6}$$

Even in the absence of a spillover ($\gamma = 0$) the wage of low-skilled workers in city c (w_c^L) depends positively on human capital intensity s_c. This is captured by the first term in (5) and arises solely as a matter of imperfect substitutability of input factors. A positive human capital

externality ($\gamma > 0$) reinforces this effect, which is represented by the second term in (5). Conversely, the impact of an increase in s_c on the high-skilled wage w_c^H is ambiguous and depends on the strength of the externality γ relative to the "neoclassical" supply effect that is represented by the first term in (6). This effect states that wages of high-skilled workers should be low where human capital is relatively abundant.[3]

As the present paper analyzes employment growth rather than wages, I assume that there is a long-run relation between these two variables. Without presenting the detailed micro-foundations for this argument by modelling endogenous migration or education choices, it seems plausible to posit that local growth of any job type should be increasing in the respective local wage rate. In particular, high-skilled employment growth should be strong in areas with a relatively high return to human capital, either because skilled migrants are attracted to these cities, or because of a higher incentive for the young local population to invest in education (see also Barro and Sala-i-Martin, 1999: ch. 9). Absence of a spillover ($\gamma = 0$) then implies, that long-run growth of high-skilled jobs is stronger in areas with a low initial human capital share, other things being equal. With $\gamma > 0$, the direction of the impact depends on whether the externality is strong enough to yield higher skilled wages in human capital abundant areas. This point can be illustrated by comparing the skilled wage in two cities i and j. Using eq. (3), one obtains

$$\log(w_i^H) - \log(w_j^H) = \gamma\left[\log(1+s_i) - \log(1+s_j)\right] - \alpha\left[\log\left(\frac{s_i}{1-s_i}\right) - \log\left(\frac{s_j}{1-s_j}\right)\right] + \left[\log(\varphi_i) - \log(\varphi_j)\right] \quad (7)$$

Skilled labor moves from city j to city i if eq. (7) is positive, and vice versa. Since we have perfect price equalization in this model, nominal wages must be equalized across cities in the long run.[4] Hence, $\log(w_i^H) - \log(w_j^H) = 0$, or

[3] As shown by Moretti (2004a), the average city wage $s_c w_c^H + (1-s_c) w_c^L$ can be increasing in s_c beyond the increase due to the private returns to education, even with $\gamma=0$. Moretti suggests analyzing the impact of human capital intensity on wages of high-skilled workers, because a positive coefficient would clearly imply a spillover. Using US data he actually finds evidence that wages of college educated workers rise with the local human capital share. In terms of the above model, this suggests not only that an externality exists ($\gamma>0$), but that it is strong enough to render localized increasing returns to human capital, $\gamma > \alpha(1+s_c)/s_c(1-s_c)$. An alternative strategy („constant composition approach") has been suggested by Ciccone and Peri (2006), who receive the conflicting conclusion that there is little evidence for a localized human capital externality in the US.

[4] In an extended model with non-tradable goods, real wages must be equalized. Shapiro (2006) uses the impact of human capital on local housing prices to disentangle between productivity and consumption amenities. He finds significant impacts of both channels. In this paper we concentrate on, and further disentangle the former.

$$\left(1+s_i\right)^{\gamma}\cdot\left(\frac{1}{s_i}-1\right)^{\alpha}\cdot\varphi_i=\left(1+s_j\right)^{\gamma}\cdot\left(\frac{1}{s_j}-1\right)^{\alpha}\cdot\varphi_j \qquad \forall i,j \tag{8}$$

The first (second) term on either side of the equation is increasing (decreasing) in s_c, $c=i,j$, and depicts the spillover and the neoclassical effect, respectively. Abstracting from exogenous city differences ($\varphi_i=\varphi_j$), eq. (8) implies that $s_i=s_j=s^*\forall i,j$ is always a long-run equilibrium. This equilibrium s^* is unique and globally stable if $\gamma=0$, hence one should observe unconditional convergence of local human capital shares over time.

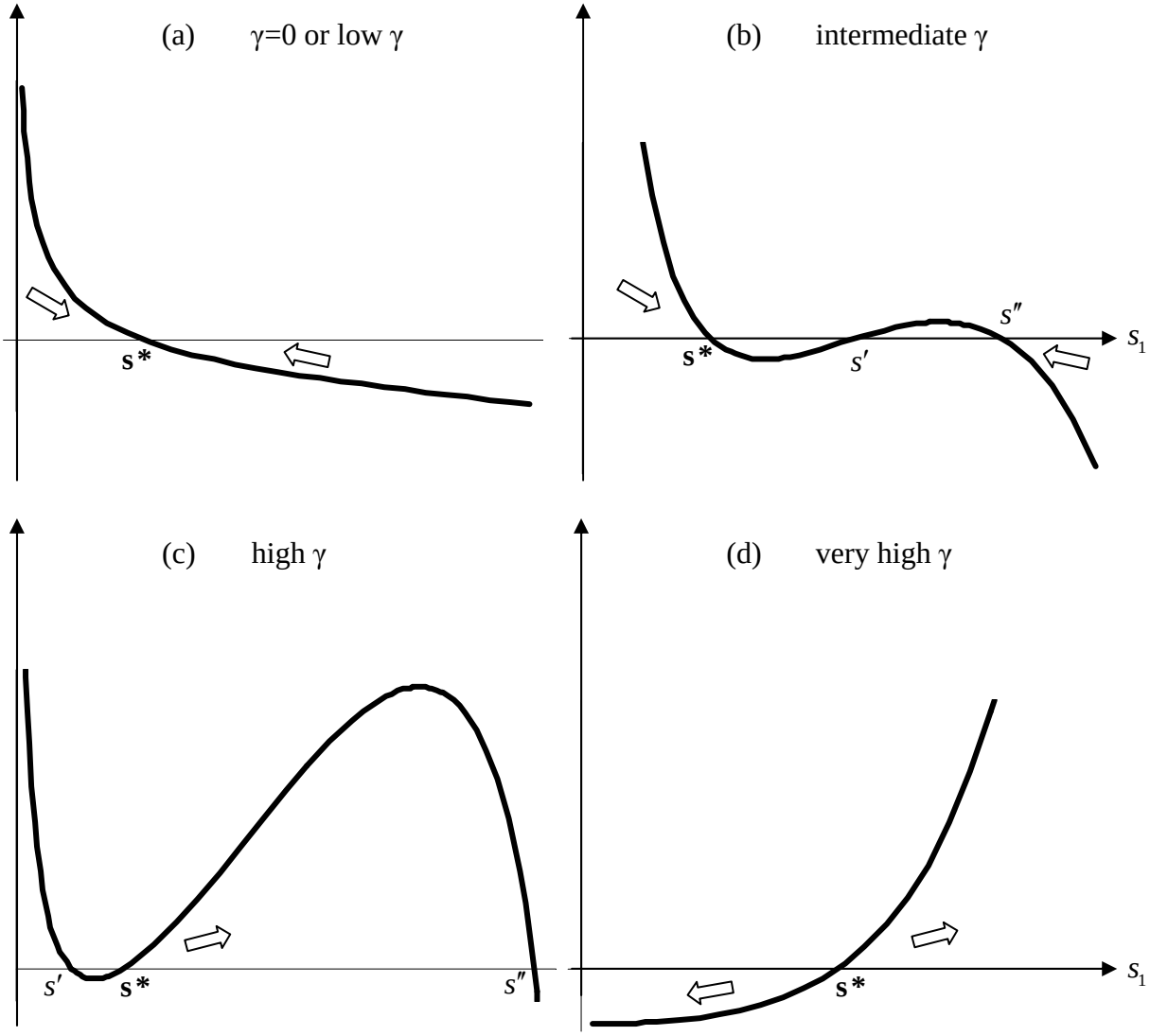
Matters are different if a sufficiently strong external effect exists. For simplicity, I focus on the evolution of the human capital share s_1 in a small city $i=1$ and suppose that the skill intensity s_j in all other cities j is constant and given by the national steady state value s^*. Substituting $s_j=s^*$ in (8) and imposing $\varphi_1=\varphi_j$, it is clear that $s_1=s^*$ must be an equilibrium configuration for city 1. But this equilibrium is not stable with $\gamma\gg 0$.

Figure 1 graphs the wage disparity $\left(w_1^H-w^{H^*}\right)$ as a function of s_1 for different values of the externality γ. For low values of γ (including $\gamma=0$), $s_1=s^*$ is unique and globally stable. The share s_1 will be increasing (decreasing) over time if the initial human capital share is below (above) s^* (panel a). As the strength of the externality increases, multiple equilibria arise. Depending on the initial conditions wage equalization may be obtained at $0<s_1\neq s^*<1$, and these interior equilibria may be locally unstable (as s' in panel b) or stable (s'' in panel b, s' and s'' in panel c). In particular, the initial human capital share s_1 can be *positively* related to its subsequent growth rate if city 1 converges to a long-run equilibrium $s_1^*>s^*$, as the equilibrium s'' in panel (c). Finally, panel (d) illustrates the most extreme configuration where externalities are strong enough to render globally increasing returns to human capital in city 1.

To sum up, long-run growth of high-skilled jobs will depend *positively* on the initial local share of high-skilled workers if a strong human capital externality exists. In case of a negative effect of the initial human capital share on high-skilled job growth I can conclude that some potential spillover is not strongly pervasive. However, a negative coefficient can not be used to reject the existence of a human capital externality completely, because it might just not be strong enough to overturn the neoclassical convergence tendency (as in panel a). In the empirical analysis, I do not aim to identify the quantitative *size* of a potential spillover γ. I

rather analyze if the evidence is in line with theories that imply a self-reinforcing process of spatial human capital concentration due to strong localized (technological or pecuniary) externalities, or if the evidence suggests a convergence of human capital shares at the local level.

Figure 1: Spillover strength and equilibrium human capital hare s_1



3) Data and descriptive overview

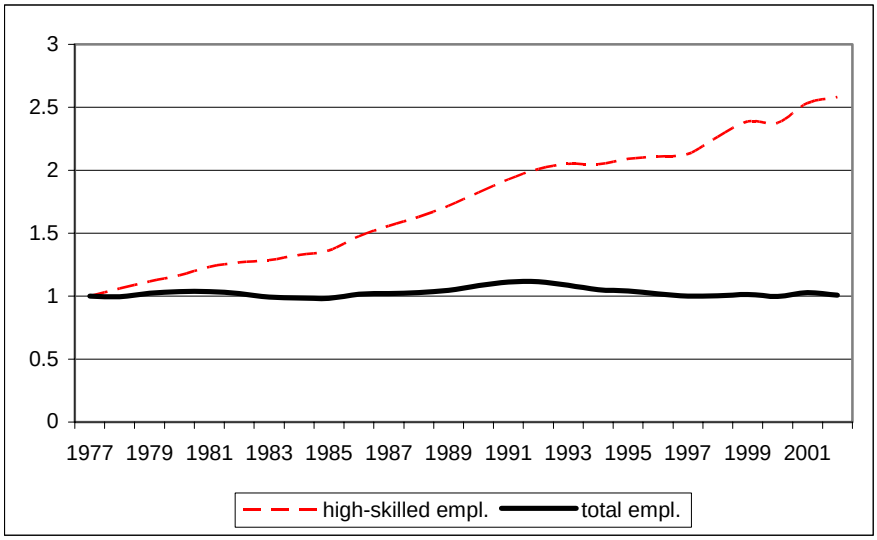
For this study I use official local employment data provided by the German Federal Employment Agency (Bundesagentur fuer Arbeit). This highly reliable official information covers the entire territory of West Germany (excluding Berlin), and the complete population of full-time employment relationships subject to social security (i.e. without civil servants and self-employed individuals) between 1977 and 2002. Employment is observed on the spatial

scale of 326 NUTS3-districts ("Landkreise" and "kreisfreie Städte"), which includes urban and rural areas. Data refer to the workplace location, and is not subject to any censoring.

Within each region employment in 28 different industries can be distinguished, encompassing the full range of economic activities. For each local industry not only the total employment level is known, but also the employment shares of three firm size classes (less than 20, less than 100, or above 100 employees), and – most important for this study – of three qualification groups. One can distinguish individuals without any vocational qualification (low-skilled workers), completed apprenticeship (medium-skilled workers), and completed university education (high-skilled workers). Total city employment is obtained by aggregating over all local industries. Human capital intensity is measured by the employment share of high-skilled workers in city c.

Since this paper presents novel evidence for Germany, I start with some descriptive statistics. Figure 2 plots the development of total full-time employment in West Germany (1977=1.00) and the respective development of high-skilled employment. Whereas the total number of full-time jobs has almost remained flat over the observation period (at about 16.2 million), the number of high-skilled jobs has more than doubled to roughly 1.5 million in 2002.

Figure 2: Total versus high-skilled employment (1977=1.00)



At the same time, there have been marked differences in the level, and in the development of the human capital intensity across districts and industries. Starting with the sectoral level, table 1 reports total employment and average human capital share across industries in 1977 and 2002, respectively, as well as the long-run industry employment growth rate. The table reveals a clear trend of structural change. Traditional primary and manufacturing sectors

disappeared rapidly, and most service industries (notably the business-related services) grew significantly faster than West Germany overall.[5]

Table 1: Human capital intensity and total employment across industries

Industry	1977		2002		employm. growth rate
	Total employment	Human cap share	Total employment	Human cap share	
Business-Related Services	517,047	0.116	1,792,783	0.172	2.467
Health Care & Social Assistance	776,213	0.071	1,335,469	0.115	0.720
Social Services	225,399	0.112	341,482	0.182	0.515
Agriculture & Forestry	103,893	0.010	153,739	0.026	0.480
Leisure-Related Services	163,990	0.071	235,361	0.164	0.435
Hotels & Gastronomy	296,640	0.003	404,696	0.008	0.364
Education	306,108	0.216	415,587	0.304	0.358
Finance & Insurance	582,966	0.034	695,828	0.123	0.194
Information & Transportation	770,190	0.010	915,136	0.028	0.188
Synthetic Materials	294,171	0.017	330,863	0.053	0.125
Motor Vehicles	909,596	0.027	945,672	0.097	0.040
Commerce	2,057,192	0.017	2,135,309	0.048	0.038
Office Supplies, IT & Optics	1,418,956	0.052	1,198,105	0.140	-0.156
Machinery	892,662	0.043	752,311	0.101	-0.157
Utilities & Electric Industry	200,676	0.058	168,430	0.138	-0.161
Paper & Printing	331,719	0.013	270,945	0.039	-0.183
Public Sector (without civ.serv.)	1,021,764	0.045	813,479	0.110	-0.204
Food & Tobacco	584,322	0.011	464,618	0.025	-0.205
Household-Related Services	162,899	0.003	121,437	0.005	-0.255
Chemical Industry	561,220	0.063	404,385	0.147	-0.279
Building & Construction	1,474,752	0.019	1,062,296	0.032	-0.280
Wood-working	373,426	0.007	263,657	0.020	-0.294
Primary Metal Manuf.	837,532	0.022	583,018	0.042	-0.304
Non-metallic Mineral Mining	208,926	0.020	129,164	0.041	-0.382
Glass & Ceramics	144,280	0.018	83,959	0.060	-0.418
Musical Instrum., Jewellery, Toys	51,055	0.007	25,256	0.024	-0.505
Mining	227,175	0.043	67,467	0.091	-0.703
Leather & Apparel	650,788	0.007	172,435	0.036	-0.735
TOTAL	**16,145,557**		**16,282,887**		**0.009**
(weighted) average		**0.037**		**0.095**	

[5] The high employment growth rate of the (relatively small) agricultural sector seems surprising. It is due to the fact that many formerly self-employed farmers formally became dependent employees and thereby part of the social security system over the observation period.

The range of human capital intensities in 2002 goes from below one per cent in hotels & gastronomy and the household-related services to above 30 per cent in the education sector. The correlation between initial skill intensity in 1977 and the industry's long run employment growth rate is 0.493, which suggests that skill intensive sectors tended to grow faster.

Moving to the regional level, in table 2 I report the five most and the five least human capital intensive districts in the years 1977 and 2002, as well as the districts with the best and the worst employment growth performance. Human capital shares differ by a factor larger than 10 across districts. The "smartest" German city is Erlangen, where the headquarters of Siemens are located. Metropolitan areas like Munich, Stuttgart, Frankfurt and Hamburg also have high employment shares of skilled workers. An interesting case is Wolfsburg, the location of the headquarters of Volkswagen. This city belonged to the least skilled cities in 1977, but then saw a rapid increase in the human capital intensity over the years (ranked 34th in 2002). Turning to employment growth, Munich and its surroundings (e.g., Freising) is a fast growing region, whereas the traditional coal and steel dominated districts from the Ruhr area (e.g. Duisburg, Gelsenkirchen) have experienced the most rapid decline.

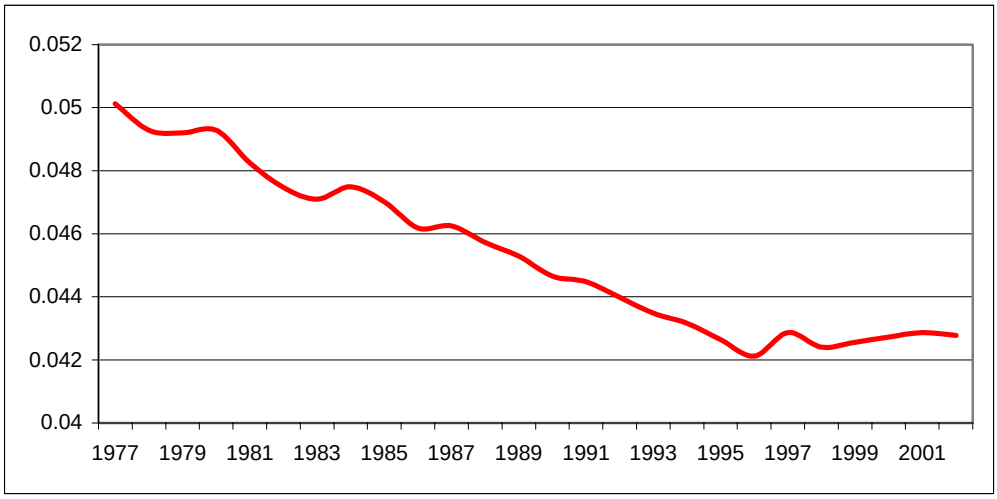
Table 2: Human capital share and employment growth, 1977 and 2002

Rank	**1977**		**2002**		**Employm. growth** (77-02)	
	District	**human capital**	**District**	**human capital**	**District**	%
1	Erlangen	0.157	Erlangen	0.268	Freising	0.642
2	Outer-Munich	0.110	Darmstadt	0.232	Outer-Munich	0.552
3	Darmstadt	0.091	Inner-Munich	0.210	Vechta	0.547
4	Frankfurt a.M.	0.082	Stuttgart	0.204	Cloppenburg	0.480
5	Inner-Munich	0.081	Outer-Munich	0.193	Main-Taunus-K.	0.467
…	…	…	…	…	…	…
322	Cochem-Zell	0.009	Schwandorf	0.029	Wunsiedel i.F.	-0.238
323	Regensburg	0.009	Südwestpfalz	0.028	Duisburg	-0.252
324	Neustadt a.d.W.	0.008	Freyung-Grafenau	0.028	Gelsenkirchen	-0.270
325	Wolfsburg	0.007	Straubing-Bogen	0.027	Südwestpfalz	-0.362
326	Südwestpfalz	0.006	Ansbach	0.025	Pimasens	-0.379

Finally, as mentioned already in the introduction, regional endowments of high-skilled labor have tended to converge over the observation period. Figure 3 illustrates the variation coefficient of human capital shares across all districts (based on the weighted standard deviation). By and large there has been a steady decline in cross-district dispersion of local human capital shares that is somewhat flattening since the mid-1990s. Together with the general tendency of skill intensities to increase over time, figure 3 suggests that high-skilled

employment grew over-proportionally in districts with a relatively small initial human capital share. This impression will be verified in the statistical analysis below.

Figure 3: Variation coefficient of local human capital shares (N=326)



4) City employment growth: empirical specification and results

I regress long-run district employment growth on local base year characteristics. As a first step I will analyze the cross-section of total employment growth rates (section 4.1). In order to discriminate between externalities and complementarities I will then turn to growth of high-skilled and low-skilled jobs, respectively, as the dependent variable (section 4.2). Finally, I use a panel setup to address the possibility of unobserved heterogeneity across local areas that may be correlated with human capital (section 4.3).

4.1. Cross-section of total city employment growth

In the cross-section analysis, I use growth rates for the period 1985-2002 as the dependent variable (by subtracting the log employment level in city c in 1985 from the respective log-level in 2002). To address issues of reverse causality, all control variables are computed for the year 1977.[6] It seems implausible to argue, e.g., that skilled workers have moved to a particular city in 1977 because they expected growth to be strong from 1985 onwards, so I am confident that endogeneity problems are avoided.

[6] I have experimented with different time periods for growth rates. To avoid outlier problems for single years I 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.

The central control variable is the initial employment share of high-skilled workers in city c in 1977. In order to analyze which skill group is particularly related to employment growth I also include the share of medium-skilled employees.

As additional controls I use the total city employment level, which captures possible misspecification of the model that is written entirely in factor shares. As the data set entails urban and rural areas, I control for (log) employment density.[7] Furthermore, I include firm size structure, because a glance at correlation tables suggests that the employment share in large firms is strongly positively correlated with the high-skilled employment share (ρ=0.550), but strongly *negatively* with employment growth (ρ= –0.502). The previous literature on human capital and city growth has usually not included firm size structures, probably due to a lack of data. This seems to be important, however, as the regression might otherwise suffer from an omitted variable bias.[8] Finally, reminiscent of the debate on education versus industry structure, I control for initial sectoral composition. One could exploit the variation of employment in 28 different industries, but in order to limit the number of results I will only report estimations where I control for the employment share of three broad industrial classes.[9] Estimation is done by using OLS with robust standard errors, because the Breusch-Pagan test indicated potential heteroskedasticity problems (with the null of spherical disturbances rejected at 0.02 confidence level in the most comprehensive specification), which may be due to the fact that the dependent variable is a growth rate of districts with quite heterogeneous initial size.

Table 3 reports the results. The impact of the initial employment share of high-skilled workers is significantly positive in all specifications. The initial share of medium-skilled employees also significantly raises total city employment growth, but the impact is considerably smaller than for high-skilled employees (see estimation 2). The positive effect of human capital is robust to the inclusion of local firm size structure and industrial composition. Comparing the baseline estimation (2) with specification (3), it becomes obvious that an omission of firm sizes leads to a downward bias in the coefficient for human capital intensity (2.0309 versus 2.1667). The reason is that university graduates are over-represented in large firms, but a high local employment share in large firms – per se – reduces growth significantly (-0.3079).

[7] To compute employment density, I divide the total employment level in city c by area size measured in square kilometres (provided by the German Federal Statistical Office).

[8] Another study that emphasises the importance of firm sizes for regional employment growth is Combes et al. (2004), who have no information on qualification structures, however.

[9] Estimations that include all 28 industry employment share lead to similar results for the impact of human capital. For the definition of the broad groups of industries, refer to the appendix. Estimation results are robust to small re-definitions of these sectoral classifications.

Table 3: Regression results – total city employment growth 1985-2002. Cross-section analysis.

total city emp. growth	(1)	(2)	(3)	(4)	(5)
High-skilled employment share	**2.1074***** (3.02)	**2.0309***** (3.10)	**2.1667***** (3.52)	**1.8151**** (2.32)	**2.3696***** (2.95)
Medium-skilled Employment share	--	**0.4455***** (3.00)	**0.3922**** (2.54)	0.2151 (1.51)	**0.3269**** (2.26)
log (total local employment level)	0.0001 (0.01)	0.0018 (0.17)	0.0114 (1.13)	0.0019 (0.19)	0.0121 (1.14)
log(empl. density)	- **0.0711***** (-9.95)	- **0.0758***** (- 10.57)	- **0.0588***** (-6.64)	- **0.0852***** (-11.42)	- **0.0604***** (-5.80)
Large firms employment share	--	--	- **0.3079***** (-3.59)	--	- **0.4072***** (-3.87)
advanced services employment share	--	--	--	0.1205 (0.66)	- 0.0725 (-0.39)
basic services employment share	--	--	--	**0.6010***** (3.70)	0.2941 (1.60)
modern manufacturing employment share	--	--	--	**0.2800***** (4.33)	**0.3057***** (4.81)
Constant term	**0.2832***** (2.82)	0.0135 (0.10)	0.0206 (0.15)	0.0093 (0.07)	- 0.0094 (-0.07)
NOBS	326	326	326	326	326
R^2	0.3249	0.3515	0.3791	0.3953	0.4205

t-value in parentheses. significance levels: ***) – 1%, **) – 5%, *) – 10%. Control variables for year 1977.

Analogously, comparing (2) and (4), an omission of industry composition leads to an upward bias in the estimate for human capital (2.0309 versus 1.8151), because high-skilled labor is positively correlated with booming industries. The impact of human capital remains qualitatively robust, however, which suggests that the positive correlation between high-skilled labor and city growth is not spurious.

The most comprehensive specification (5) shows a positive effect of the initial human capital share that is considerably larger as compared to previous findings for the US. My findings suggest that an increase of the employment share of high-skilled workers by one percentage point raises local employment growth by roughly 2.37 per cent.[10] 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). Apart from several details (they use population, whereas I use employment data; their time period of 10 years is shorter than the one I use; etc.), it appears that one important reason for the large quantitative difference is the definition of what is a "high-skilled worker". The group of high-skilled workers in my data set 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. My 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 from an applied perspective. When university graduates and medium-skilled workers are lumped together in one skill group that appears better comparable to a Bachelor's degree, I obtain a coefficient of 0.3625** (t-value 2.44) when redoing estimation (5), which is perfectly in line with the findings of Glaeser and Saiz (2004). The finer decomposition of high-skilled workers in my data set suggests that the positive impact of human capital on city growth is mostly driven by workers with formal education beyond the Bachelor's level.

Turning to the other coefficients, I find a negative relation between initial employment density and subsequent employment growth, as well as a negative impact of large firms. The negative impact of density suggests that the German economy is subject to a long-lasting process of spatial employment de-concentration (or, sub-urbanization), as metropolitan areas tend to loose employment shares to surrounding districts. For the initial sectoral composition, I find a positive impact of the initial employment share in modern manufacturing industries.

[10] The standard deviation of district growth is around 0.14, and the standard deviation of the high-skilled employment share is around 0.02. Thus, an increase in the high-skilled employment share by one standard deviation raises subsequent employment growth by more than one third of a standard deviation.

4.2. Employment growth by skill group

In Germany, a city's initial human capital intensity is robustly positively related to its subsequent total employment growth. This result is qualitatively and quantitatively in line with previous findings for the US. What is the causal link underlying this positive relationship? Glaeser and Saiz (2004) argue that the main channel is productivity. But it is unclear whether human capital externalities are pervasive at the local level, or if the positive relation is mainly due to complementarities that are consistent with a neoclassical production function not exhibiting any spillover. As explained in section 2, I analyze growth separately for high-skilled and low-skilled jobs to discriminate between externalities and complementarities.

More precisely, I re-estimate the most comprehensive specification of the previous cross-section analysis (column 5 in table 3), and exchange the dependent variable with the growth rate of high-skilled (low-skilled) jobs, or – respectively – with the growth rate of the local employment share of high-skilled workers between 1985 and 2002. As before, all control variables are computed for the year 1977.

Table 4 shows the results. Columns (1) and (2) refer to growth of low-skilled jobs, and for the combined group of low- and medium-skilled jobs. Column (3) refers to the growth rate of high-skilled jobs, and column (4) to the growth rate of the local human capital *share*. This specification is most closely related to the theoretical model from section 2.

The central finding of this study can be summarized as follows: Whereas the initial share of high-skilled workers significantly raises growth of low-skilled and (to a somewhat lesser extent) of medium-skilled jobs, it significantly reduces growth of high-skilled jobs (-2.6714). Inter alia, the intial *level* and the subsequent *growth rate* of the local human capital share are significantly negatively related (-5.0499). High-skilled jobs have grown stronger in local areas with low initial human capital intensity. Employment shares of high-skilled workers across space should, therefore, become more equal over time. This is consistent with the descriptive evidence as reported in figure 2 above.

This evidence is in line with complementarities among skill groups. Low-skilled workers benefit from the local presence of human capital. There also is a positive, yet smaller effect of medium-skilled employees on subsequent low-skilled employment growth (0.8896), whereas the effect on high-skilled employment growth is insignificant. I even find a (significantly) negative impact on the growth rate of the human capital share (-0.3547), which would suggest that high- and medium-skilled workers are substitutes rather than complements. This impression does not turn out to be robust to the inclusion of fixed effects, however.

Table 4: Regression results – city employment growth by skill groups (1985-2002)

	(1)	(2)	(3)	(4)
	Low-skilled empl. growth	**Low-+ medium-empl. growth**	**High-skilled empl. growth**	**Growth human capital share**
High-skilled employment share	**5.6802***** (4.37)	**1.9610***** (2.59)	**- 2.6714**** (-2.04)	**- 5.0499***** (-5.37)
Medium-skilled Employment share	**0.8896***** (3.64)	**0.3480**** (2.44)	- 0.0274 (-0.12)	**- 0.3547*** (-1.87)
log (total local employment level)	**0.0537***** (3.14)	0.0091 (0.89)	0.0084 (0.41)	-0.0037 (-0.24)
log(empl.density)	**-0.0412**** (-2.44)	**- 0.0634***** (-6.24)	- 0.0147 (-0.41)	**0.0459***** (3.06)
Large firms employment share	**-1.0446***** (-5.99)	**- 0.4061***** (-3.95)	**- 0.5937***** (-2.62)	- 0.1889 (-1.06)
advanced services employment share	-0.3859 (-1.40)	- 0.1670 (-0.95)	0.2824 (0.73)	0.3557 (1.32)
basic services employment share	**0.8126***** (2.86)	**0.3132*** (1.77)	- 0.3349 (-0.95)	**- 0.6329**** (-2.47)
modern manufacturing employment share	**0.2142**** (2.01)	**0.2703***** (4.45)	**0.5075***** (3.82)	**0.2001**** (2.00)
Constant term	**-0.8447***** (-3.92)	0.0163 (0.13)	**0.9167***** (4.09)	**0.9295***** (5.24)
NOBS	326	326	326	326
R^2	0.3918	0.4701	0.2291	0.1973

t-value in parentheses. significance levels: ***) 1%, **) 5%, *) 10%. Control variables for 1977

4.3. Panel analysis

The results have relied on a cross-section approach so far. However, human capital might proxi for unobserved local characteristics that drive employment growth. To address this issue, I make use of the longitudinal structure of the data set and turn to panel estimation with fixed effects in this subsection. I split up the observation period into three parts, and compute employment growth rates for the following periods: 1980-1985, 1988-1993 and 1996-2002. Control variables for the three periods are, respectively, computed for 1977, 1985 and 1993. Using independent variables with a sufficiently long time lag again ameliorates concerns of reverse causality.[11] This procedure gives three observations for each local area, and thus a total number of $3 \times 326 = 978$ observations.

[11] The results are not sensitive to the choice of these particular time periods. I have experimented also with different base years, and other growth periods (in particular, I have also used panels where the total observation period is split up in two or in four time periods). The results are qualitatively similar.

Estimation is done separately for total city employment growth, growth of low-skilled jobs, growth of high-skilled jobs, and the growth rate of the local human-capital share as the dependent variable. Table 5 shows the results for the panel estimations with robust standard errors, where I include fixed effects for each local area and time period.[12] The same set of control variables as in the previous subsection was used, except that total city employment level now has to be dropped due to collinearity with density as area size in km^2 does not vary over time . For brevity, I only report results for the impact of the employment share of high-skilled and medium-skilled workers, because the other estimated coefficients (density, large firms, industrial composition) do not change qualitatively.

Table 5: Panel analysis (1980-1985, 1988-1993, 1996-2002) – Fixed effects estimation

	(1)	(2)	(3)	(4)
	Total empl. growth	**Low-skilled empl. growth**	**High-skilled empl. growth**	**Growth human capital share**
High-skilled employment share	0.2058 (0.53)	**1.2396*** (1.81)	**- 4.8101***** (-5.46)	**- 5.0160***** (-6.61)
Medium-skilled Employment share	0.0813 (0.65)	**0.7314***** (2.74)	- 0.0416 (-0.13)	-0.1229 (-0.46)
Other controls	log(emp.density), empl.share in large firms, empl. share in advanced services, basic services, modern manufact., constant term.			
local area fixed effects	YES	YES	YES	YES
time period fixed effects	YES	YES	YES	YES
NOBS	978	978	978	978
R^2	0.7440	0.8279	0.5210	0.5042

t-value in parentheses. significance levels: ***) 1%, **) 5%, *) 10%.
Control variables for 1977, 1985, 1993 (depending on period)

Controlling for fixed effects renders insignificance of the relation between the initial human capital share and *total* employment growth, but it does not affect the main result that was conveyed in the cross-section analysis. The initial employment share of high-skilled workers

[12] This is the strictest formulation of the fixed-effects model. Identification of the impact of human capital comes solely from the change in the high-skilled employment share within a district. In their analysis on US cities and MSAs, Glaeser and Saiz (2004) argue that this approach is "asking a great deal from the data", because there is persistence in human capital over time and the local fixed effects eliminate most of the variation of human capital across space. A weaker version would only use fixed effects for states (Bundesländer), or area types. I have experimented with these regional fixed effects as well, but opted for the strictest form of fixed effects, as this gives most confidence on the robustness of results.

is significantly positively related to growth of low-skilled jobs (1.2396). The impact on subsequent growth of high-skilled jobs (-4.8101) and, respectively, on growth of the human capital share (-5.0160) remains significantly negative.

Quantitatively, the inclusion of fixed effects works in the expected direction with respect to the impact of the high-skilled employment share. In panel estimations without fixed effects (not reported) I receive significant and considerably larger positive coefficients in the estimations for total and low-skilled employment growth, and smaller negative (yet still significant) coefficients in the regression for growth of high-skilled employment. Idiosyncratic city effects seem to positively covary with human capital. Hence, not controlling for the fact that certain locations seem to constantly attract high-skilled workers by including fixed effects leads to an overstatement of the impact of human capital on total and low-skilled employment growth, and – respectively – to an understatement of the equilibrating forces of local human capital shares.

Results are not driven by the fact that my data set includes small cities and local areas with rural character. Re-doing the fixed effects estimation for the sub-sample of large German cities[13] yields a coefficient of –2.7636** (t-value: -2.61) for the impact of the initial human capital share on its subsequent growth rate. Equilibrating forces appear to be weaker among large cities than among West German local areas overall (where the respective effect has been –5.016***), but the results remain qualitatively unaffected.

In sum, neither the cross-section nor the longitudinal analysis lend empirical support to strongly pervasive localized human capital externalities. However, as explained above, one should not conclude that spillovers are entirely rejected by these empirical findings. They might actually exist, but they are not strong enough to compensate the "neoclassical" convergence tendency of local human capital shares.

5) Growth of local industries: empirical specification and results

In this final section I move the unit of observation from local areas down to the single local industries. This allows analyzing if the impact of human capital on employment growth may have a cross-industry component. Specifically, I relate the employment growth rate of some industry i located in city c to the own-industry share of high-skilled workers in (i,c), *and* to the human capital share of the other industries in the same city.

[13] "Large city" = area type 1 of the BBR-classification scheme of German districts, 39 observations per period.

I stick to the panel setup described in section 4.3. For the three time periods under consideration (1980-1985, 1988-1993, 1996-2002), I compute the growth rate of total, low-skilled and high-skilled employment, and of the human capital share for every local industry (i,c). These growth rates are, respectively, used as the dependent variable. As local industries are sometimes very small, growth rates exhibit exorbitant jumps following small absolute employment changes.[14] This erratic noise in the data will yield R^2 levels that are considerably smaller than before, in particular for regressions referring to high-skilled employment growth. Furthermore, heteroskedasticity problems are exacerbated, so that the use of robust standard errors has to be continued.

As right-hand side variables I use the standard set of time-lagged controls, i.e. (log) employment density of city c, the employment share in large firms in local industry (i,c), and the own-industry employment share of high- and medium-skilled workers in (i,c). As the first new explanatory variable, I compute the aggregate share of high-skilled workers in city c minus the respective own-industry human capital share,

$$aggregate\ city\ human\ capital_{i,c} = \frac{high-skilled_c}{emp_c} - \frac{high-skilled_{i,c}}{emp_{i,c}} \qquad (9)$$

The theoretical rationale for including this variable hinges on the presumption that factor markets are not perfectly integrated across industries at the local level. Suppose, for the sake of the argument, that there is no sectoral mobility of workers. According to the neoclassical model developed above, high-skilled job growth in any particular industry should be stronger where returns to human capital are relatively high, hence, where high-skilled labor is initially relatively scarce. This gives rise to the expectation that the initial own-industry human capital share should be negatively related to its subsequent growth across local industries if γ is weak. At the same time, the relative scarcity of, and the returns to high-skilled workers in one industry should be unrelated to the human capital intensity of other industries when there is zero sectoral mobility.[15] Now suppose there is a localized human capital externality that occurs between industries, and consider the following example. With un-integrated local

[14] For example, 597 out of 9128 local industries in the year 1977 had less than 20 full-time employees in total. In 1959 cases there was not a single high-skilled employee.

[15] One can tell reasonable stories why this coefficient could be negative. E.g., if factor markets are integrated across industries, the returns to human capital in every industry should be generally low in initially skilled cities. High-skilled job growth in local industry i,c could then negatively depend on the city's aggregate human capital share according to neoclassical presumptions, because the large supply of high-skilled workers drives down the local returns to human capital. "Labor poaching" (see Combes and Duranton, 2006) might be an alternative hypothesis. It turns out, however, that a negative coefficient associated with (9) is empirically not relevant.

factor markets, human capital in industry 1 does not drive down the wage for high-skilled workers in industry 2 through the usual supply effect. Industry 2 might, however, benefit from human capital in industry 1 through external knowledge flows. In this case, job growth in 2 depends *positively* on the human capital intensity of industry 1. Thus, if I find that local industries benefit from the local availability of human capital in other sectors (i.e., a positive coefficient associated with (9)), this would be consistent with an inter-industry human capital externality.

In addition to the aggregate human capital share of city c that, from the point of view of industry (i,c), refers to the total *stock* of high-skilled workers in other industries, I construct an index for the degree of specialization of surrounding local knowledge in the following way,

$$skill\ specialization_{i,c} = \sum_{s=1, s\neq i}^{S} \left| \frac{high-skilled_{s,c}}{emp_{s,c}} - \frac{high-skilled_{s}}{emp_{s}} \right|, \qquad (10)$$

i.e. the sum of absolute differences of local minus national human capital intensities across all other industries S. This index is equal to zero if the surrounding local skill structure exactly matches the national average, and it increases with the degree of idiosyncrasy of the local environment. If the coefficient on this variable is significant, local industries (i,c) are affected by the surrounding *skill structure*, holding constant the *total stock* of regional human capital. This would also suggest the presence of some localized external transmission channel across industries. In particular, a significantly positive coefficient suggests that local industries benefit from specialized surrounding knowledge.[16]

In the panel estimation I include industry-, city- and time-period fixed effects. Table 6 reports the regression results when all private, non-primary local industries are lumped together. With respect to the own-industry employment shares of high-skilled and medium-skilled workers, the results for local industries resemble what I have found for entire cities. The initial share of high-skilled workers is insignificant for total employment growth (column 1). It is positively related to low-skilled employment growth (0.6899, column 2), but negatively related to growth of high-skilled jobs (-4.1992, column 3). Inter alia, the impact of the initial level on the growth rate of the human capital share is significantly negative (-4.3503). Strong localized spillovers that would render increasing returns to human capital within industries and trigger a

[16] This issue is related to the literature on diversity vs. specialisation that was launched by Glaser et al. (1992) and Henderson et al. (1995). An analysis on West Germany that follows this strand has been provided by Blien et al. (2006). For a survey, see Combes and Overman (2004). This literature has focussed on the impact of the industry structure of *overall* employment on growth of local industries, however, and has remained quite silent on the (relative) importance of human capital.

spatial concentration process of high-skilled labor are, again, rejected. Moreover, the coefficients for the aggregate local human capital share, and the degree of knowledge specialization, which were both included to gather evidence for the potential existence of cross-industry spillovers, are both insignificant when it comes to high-skilled employment. There is a positive effect for total employment growth (0.1953), which is driven by an effect on medium-skilled employment. But this impact can, again, represent skill complementarities rather than spillovers.

Table 6: All local industries, panel analysis (1980-85, 1988-93, 1996-02), fixed effects

	(1)	(2)	(3)	(4)
	Total employment growth	**Low-skilled empl. growth**	**High-skilled empl. growth**	**Growth human capital share**
own-industry empl.sh. high-skilled	0.0126 (1.47)	**0.6899***** (6.15)	**- 4.1992***** (-5.66)	**- 4.3503***** (-5.18)
own-industry empl.sh. medium-skilled	0.0031 (1.26)	**0.5359***** (12.54)	0.5152* (1.95)	0.3021 (1.41)
aggregate city human capital	**0.1953***** (3.91)	0.3654 (0.69)	- 2.9716 (-0.89)	- 3.3647 (-1.04)
Skill specialization	0.0025 (0.80)	- 0.0649 (1.64)	0.2927 (1.07)	0.2479 (0.91)
log(empl.density)	-0.1976*** (-36.78)	**-0.0155***** (-2.98)	**-1.0693***** (-2.76)	**- 0.9706**** (-2.59)
Large firms employment share	0.0002 (0.12)	**-0.2322***** (-15.14)	**-0.3323***** (-3.16)	**- 0.2162**** (-2.19)
Constant term	**0.3691***** (25.79)	**0.8517**** (2.08)	**7.8123***** (2.58)	1.4178 (1.54)
Industry fixed effects	YES	YES	YES	YES
local area fixed effects	YES	YES	YES	YES
time period fixed effects	YES	YES	YES	YES
NOBS	22494	21888	22225	22494
R^2	0.7287	0.2168	0.0272	0.0219

t-value in parentheses. significance levels: ***) 1%, **) 5%, *) 10%.
Control variables for 1977, 1985, 1993 (depending on period)

From these figures, evidence on human capital externalities appears rather slim, because growth of high-skilled employment is neither spurred by the own-industry human capital share, nor by the human capital intensity of other industries. However, some more specific developments might be hidden in the data that are not captured in a global regression including all industries.

I repeat the panel estimation and put local industries together in four sub-samples – modern manufacturing, advanced services, traditional manufacturing, and basic services (described in the appendix). This exercise is helpful for addressing whether evidence for within- or across-industry human capital externalities exists at least in some cases. Results are presented in table 7. I only report the estimations for the growth rate of the human capital share, because this is the crucial dependent variable for identifying potential spillovers. Furthermore, I omit the coefficient for all background controls that do not refer to human capital.

Table 7: Growth rate human capital share – by industry type, panel analysis

dependent variable: growth rate of human capital share (i,c)	(1) **modern manufacturing**	(2) **advanced services**	(3) **traditional manufacturing**	(4) **basic services**
own-industry empl.sh. high-skilled	**- 3.3234***** (4.61)	**- 1.5974***** (-3.05)	**- 11.212***** (-3.50)	**- 11.114***** (-4.19)
own-industry empl.sh. medium-skilled	0.1974 (0.49)	0.1905 (0.37)	0.3680 (1.45)	1.1509 (1.20)
aggregate city empl.sh. high-skilled	**3.7229**** (2.00)	**2.6291**** (2.18)	-0.1431 (-0.07)	- 0.1778 (-0.05)
Skill specialization	0.1216 (0.59)	**0.4301**** (2.51)	0.0603 (0.28)	0.5073 (1.50)
Other control variables	log(emp.density$_c$), empl.share in large firms$_{i,c}$, fixed effects, constant term.			
NOBS	3912	4890	9780	3912
R^2	0.0881	0.0863	0.0430	0.0749

t-value in parentheses. significance levels: ***) 1%, **) 5%, *) 10%. Growth periods: 1980-1985, 1988-1993, 1996-2002. Control variables, respectively, for 1977, 1985, 1993.

For all four groups I find that the initial own-industry human capital intensity remains significantly negatively related to its subsequent growth rate. However, the strength of equilibrating forces for local human capital shares differs profoundly between industries. Neoclassical convergence tendencies appear to be particularly strong in traditional manufacturing (-11.212), and in basic service industries (-11.114). They are considerably weaker (though still dominant) in modern manufacturing (-3.3234), and in advanced service industries (-1.5974). This seems plausible, because a priori one would probably have expected human capital externalities to be more important in these two cases.

Moreover, for these two broad sectors I find a significant impact of the surrounding local human capital. In both cases I obtain a significantly positive coefficient for the aggregate local human capital intensity (3.7229 for modern manufacturing, 2.6291 for advanced services). Both sectors tend to benefit from a higher stock of human capital in the local neighbourhood.

In addition, growth of advanced service industries is spurred by the degree of specialisation of this surrounding local human capital (0.4301). These results suggest that localized, inter-industry human capital externalities play a role for modern manufacturing and advanced service industries, but not for basic service and traditional manufacturing industries.

6) Conclusion

Skilled cities grow faster than unskilled ones, on aggregate. However, this paper casts doubts on whether this positive relation is due to human capital spillovers at the local level. I find that a large initial share of high-skilled workers significantly reduces subsequent growth of high-skilled jobs. This emphasizes the importance of a "neoclassical" mechanism, according to which human capital should grow stronger in locations were it is initially relatively scarce. Potential human capital externalities are not strong enough to off-set this tendency. At the same time, spillovers are apparently not equal to zero. Some evidence for a positive cross-industry effect of human capital on subsequent high-skilled employment growth is found for modern manufacturing and advanced service industries. Still, there is no indication that human capital externalities lead to a self-reinforcing process of spatial human capital concentration in these cases.

Appendix: Definition of broad industry groups

A) Modern manufacturing – utilities & electric industry, synthetic material, machinery, motor vehicles, office supplies, IT & optics.

B) Ad*vanced service industrie*s – finance & insurance, health care, business-related services, education, leisure-related services, social services.

C) *Basic services* – commerce, information & transportation, hotels & gastronomy, household-related services.

D) Traditional manufacturing – chemical industry, non-metallic mineral mining, glass & ceramics, muscal instruments & jewellery, wood-working, paper & printing, leather & apparel, food & tobacco.

E) Other – building & construction, agriculture, mining, public sector.

Advanced services and *modern manufacturing industries* are distinguished by being relatively skill-intensive on average.

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