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The Wage Effects of Regional Brain Gain and Brain Drain Revisited

Johann Eppelsheimer^{*} and Joachim Möller[†]

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Preliminary, not to be cited.

Abstract

Since the study by [Moretti \(2004\)](#) for the US, it is widely accepted that the spatial distribution of human capital plays an increasing role for regional labor market outcomes. Like in the pioneer approach we assume that workers' productivity at the firm level depend on the regional share of the high skilled. We extend the theoretical framework, however, by decomposing the change in the regional share of high-skilled workers into brain drain, brain gain as well as into labor market entry and exit effects. This allows us to investigate hypotheses about the extent and nature of knowledge spillovers in more detail.

For the empirical part we analyze a large administrative panel data set. Including a series of controls as well as fixed effects for the worker, occupation, industry, region and year we find a significant negative relationship between brain drain and the regional wage level of low- and high skilled workers and a positive one for brain gain. These results are robust across different specifications and hold for Germany as a whole and West Germany alone. If estimated separately, we find much weaker and partly statistically not significant knowledge spillovers for East German regions. In general, brain drain and brain gain effects are of similar order of magnitude, whereas the effect of labor market exits of high-skilled workers exceeds that of labor market entries in absolute value. Using instrumental variable methods we show that the basic results are not driven by endogeneity bias.

KEYWORDS: BRAIN DRAIN, BRAIN GAIN, HUMAN CAPITAL EXTERNALITIES, SMART CITIES, REGIONAL MOBILITY

JEL CLASSIFICATION: D62; J24; J31; O15; R10

1 Introduction

Workers seem to profit from face-to-face contacts to other workers. They expand their knowledge and improve their abilities if they are surrounded by others at the same location. Especially the presence of high-skilled workers is thought to be

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a source of such human capital externalities or knowledge spillovers (e.g. [Marshall 1890](#); [Lucas 1988](#)). Knowledge spillovers can be seen as a main driving force behind technological change and productivity advancement ([Acemoglu 1998](#)).

There is a growing amount of literature investigating the impact of local human capital on individual wages (e.g. [Rauch 1993](#); [Acemoglu and Angrist 2001](#); [Ciccone and Peri 2006](#); [Rosenthal and Strange 2008](#)). Particularly the framework suggested by [Moretti \(2004\)](#) caught much attention. Using a simple production function with low-skilled and high-skilled labor as inputs he establishes a link between productivity and the regional share of high-skilled workers. Higher productivity through higher knowledge intensity of a location translates into higher earnings. Applying a Mincerian wage equation, this relationship was empirically confirmed with data for the US. With the same estimation strategy the basic results were corroborated by several follow-up studies for other countries (e.g. [Bratti and Leombruni 2011](#); [Liu 2014](#)). For Western Germany [Heuermann \(2011\)](#) finds significant wage gains due to higher local shares of high-skilled workers. Given the uneven distribution of human capital and wages across regions this is highly relevant from a regional policy perspective in Germany ([Brakman et al. 2004](#); [Südekum 2008](#)).

In Moretti's approach dynamic composition effects of the pool of high-skilled workers do not play a role. There are good reasons, however, to assume that a brain drain through the emigration of a certain number of high-skilled workers is typically not exactly compensated by an inflow of the same number of workers of the corresponding skill category. If, for instance, knowledge spillovers work through networks, a high-skilled newcomer in a region has less impact on other workers than a well-embedded incumbent person. Moreover, the heterogeneity of high-skilled with respect to age and experience is likely to be relevant. Hence, it can be expected that a high-skilled person who is going to retire has a different impact on knowledge spillovers compared to a new entrant into the labor market with similar skills. In our study we therefore extend the framework proposed by [Moretti \(2004\)](#) by separating the effects of different categories of high-skilled workers on the local knowledge pool. We decompose the impact of total local human capital on knowledge spillovers into the positive contribution of stayers and newcomers and the negative one of retiring or out-migrating persons. On the brain gain side we differentiate between new entrants into the labor market and inflow of high-skilled to the local labor market through migration.

In Moretti's theoretical model productivity of agents depends positively on their own efficiency and the local share of high-skilled workers. A growing proportion of high-skilled workers in a location unfolds two effects: a (neoclassical) labor supply effect and a human capital spillover effect. The supply effect stems from the

assumption of imperfect substitution between the two skill groups. Other things being equal, a net increase in the number of high-skilled individuals in a location leads to relative scarcity of low-skilled labor. Then standard theory suggests productivity gains for low-skilled workers relative to high-skilled workers. Human capital spillovers increase the productivity of both skill types. In total, low-skilled individuals should profit from a rising share of high-skilled labor, whereas the effect on high-skilled workers is ambiguous because the supply and spillover effect work in different directions.

We expand this framework to build a link between the development of wages of different skill groups and dynamic changes in the local human capital through brain gain and brain drain. We present a decomposition equation for the current share of high-skilled workers depending on its lagged value, brain gain and brain drain through migration as well as through exits and entries into the labor market. The production framework is extended accordingly so that productivity depends on the various components of local human capital. Theoretically we show that brain gain (brain drain) increases (lowers) wages of low-skilled workers. As in Moretti's model the effects on earnings of high-skilled workers are ambiguous due to opposing supply and spillover effects. The difference between effects caused by in- and out-migrating workers depends on the according spillover size.

We investigate the implications of the extended model using a large administrative micro panel data set for Germany. This is done for the country as a whole and for the eastern and western part separately. All three stages of the human capital decomposition are analyzed. First, we estimate a Mincerian wage equation similar to that used by [Moretti \(2004\)](#) with the actual regional share of skilled workers. Then we take a look at a intermediate version of our model including the lagged regional share of skilled labor and the difference between the current and the lagged share. Finally we test a wage equation including brain drain and brain gain components explicitly. All models contain a rich set of individual controls as well as firm, industry and regional characteristics. We also include individual, industry, regional, occupation and time fixed effects. Various alterations of our model serve as robustness tests.

As a possible critique of the empirical model one might argue that brain drain and brain gain is endogenous. To control for time-varying region-specific shocks, we use different variants of an instrumental variable approach. The lagged number of grammar schools within a certain distance to a county serves as an instrument for brain gain. The occurrence of mass-layoffs is used as an instrument to predict the regional brain drain. Additionally we use a straightforward method to compare the results of the model with the decomposed share of skilled workers with Moretti's

standard model. Overall we find strong evidence for the theoretical implications that brain drain is linked to significant wage losses whereas brain gain is associated with significant wage gains. Moreover, there are some indications that the effects are not symmetrical. We take this as evidence that Moretti’s model should be extended to capture the the impact of different components of local human capital on labor market outcomes adequately.

The paper is organized as follows. In section 2 the theoretical model and the econometric approach are described in detail. Section 3 contains information on the data used and some descriptive statistics about the spatial allocation of human capital and wages in Germany. In section 4 we present our econometric findings and various robustness checks. Section 5 concludes.

2 Framework of the Analysis

2.1 The Theoretical Model

Our starting point for analyzing the relationship between the aggregate local human capital and individual wages in a location is Moretti’s model (Moretti (2004)). Based on this, we decompose the level of human capital in each region in its lagged value and the change between the lagged and the current value. In turn this change can be decomposed into brain drain, brain gain, entries of young high-skilled workers into the labor market and exits of older high-skilled workers from the labor market.

Moretti (2004) employs a local production function depending on the amount of high-skilled labor, H_{rt} , and low-skilled labor, L_{rt} .¹ Assuming a Cobb-Douglas technology output in region r at time t can be expressed by

$$Y_{rt} = \left(\theta_{rt}^H H_{rt}\right)^\alpha \left(\theta_{rt}^L L_{rt}\right)^{1-\alpha}, \quad (1)$$

where $\theta^j, j \in \{L, H\}$ stands for a factor specific productivity parameter. Let the total number of workers in a location be $N_{rt} = H_{rt} + L_{rt}$. Then the share of high-skilled workers is defined as $h_{rt} := H_{rt}/N_{rt}$. The productivity of a worker of a skill group j , depends on the productivity ϕ^j they belong to (with $\phi^H > \phi^L$) and the share of high-skilled labor h_{rt} :

$$\ln \theta_{rt}^j = \phi^j + \gamma^j h_{rt}, \quad j \in \{L, H\}. \quad (2)$$

¹As suggested by Heuermann (2011) we drop physical capital from the production function to simplify the model without changing the results qualitatively.

The intensity of human capital spillovers is captured by $\gamma^j \geq 0$ which we model here as skill specific because the spillover effects might differ between high-skilled and low-skilled workers.² Assuming that wages are equal to marginal productivity and the efficiency parameters θ_{rt}^j are exogenous to the individual firms, log wages for low-skilled and high-skilled workers in region r are given as

$$\ln w_{rt}^L = \ln(1 - \alpha) + \alpha \ln h_{rt} - \alpha \ln(1 - h_{rt}) + \alpha \ln(\theta_{rt}^H) + (1 - \alpha) \ln(\theta_{rt}^L) \quad (3)$$

$$\ln w_{rt}^H = \ln \alpha - (1 - \alpha) \ln h_{rt} + (1 - \alpha) \ln(1 - h_{rt}) + \alpha \ln(\theta_{rt}^H) + (1 - \alpha) \ln(\theta_{rt}^L) \quad (4)$$

The first derivatives of the log wage equations show the effects of an increasing share of skilled workers

$$\frac{d \ln w_{rt}^L}{d h_{rt}} = \gamma + \frac{\alpha}{h_{rt}(1 - h_{rt})}, \quad (5)$$

$$\frac{d \ln w_{rt}^H}{d h_{rt}} = \gamma - \frac{1 - \alpha}{h_{rt}(1 - h_{rt})} \quad (6)$$

where $\gamma := \alpha\gamma^H + (1 - \alpha)\gamma^L$. On the one hand, both skill groups gain from a higher share of skilled labor through human capital externalities (i.e. $\gamma > 0$) to an equal amount. The neoclassical supply effect on the other hand affects wages of low-skilled and high-skilled individuals differently. Assuming imperfect substitution between the two groups in the production process, an increasing number of high-skilled workers makes low-skilled workers relatively scarcer. Therefore, neoclassical theory suggests relative productivity losses (gains) for high-skilled (low-skilled) workers. As a result, the low-skilled should unambiguously benefit from a rising number of high-skilled workers, whereas the impact on high-skilled workers is ambiguous. For the former the spillover effect and the neoclassical effect work in the same direction, while the two effects work in different directions for the latter.

Previous empirical studies find significant positive effects of regional concentration of human capital on wages of highly qualified workers (e.g. [Moretti 2004](#), [Heuermann 2011](#), [Bratti and Leombruni 2011](#)). This indicates that human capital spillovers overcompensate the imperfect substitution effect.

The aim of our analysis is to introduce dynamic aspects in order to analyze brain drain and brain gain effects among others. This requires an extension of the original theoretical framework. First we define the change in the share of high-skilled workers

²There are good reasons to believe that knowledge spillover effects are more intensive between high-skilled workers compared to low-skilled workers. This would imply $\gamma^H > \gamma^L \geq 0$.

from period $t - k$ to period t as

$$\Delta^k h_{rt} := h_{rt} - h_{r,t-k} = \frac{H_{rt}}{N_{rt}} - \frac{H_{r,t-k}}{N_{r,t-k}}. \quad (7)$$

Expanding equation (7) with $H_{r,t-k}/N_{rt}$ and rearranging gives:

$$\Delta^k h_{rt} = \frac{\Delta^k H_{rt}}{N_{rt}} - \frac{\Delta^k N_{rt}}{N_{rt}} h_{r,t-k} \quad (8)$$

This transformation allows us to explicitly address the total change in high-skilled workers ($\Delta^k H_{rt}$). Now we simply view the total change in high-skilled workers from $t - k$ to t as the sum of emigration E_{rt} , immigration I_{rt} , entries into G_{rt} and exits X_{rt} from the labor market for this group of workers. Moreover, we introduce an component, U_{rt} , to account for temporal absence from the labor market of high-skilled individuals³, hence

$$\Delta^k H_{rt} = -E_{rt} + I_{rt} + G_{rt} - X_{rt} + U_{rt}. \quad (9)$$

Additionally we rewrite the current share of high-skilled workers as the sum of the lagged share of high-skilled workers plus the change in the share of high-skilled workers: $h_{rt} = h_{r,t-k} + \Delta^k h_{rt}$. Combining this with equations (8) and (9) yields:

$$h_{rt} = \frac{h_{r,t-k}}{1 + \hat{n}_{rt,t-k}} - e_{rt} + i_{rt} - x_{rt} + g_{rt} - u_{rt}, \quad (10)$$

where $\hat{n}_{rt,t-k}$ denotes the growth rate of total employment between $t - k$ and t and small letters indicate the rates of the corresponding variables, e.g. $e_{rt} := E_{rt}/N_{rt}$. To introduce a more compact notation we define $\tilde{h}_{r,t-k} := h_{r,t-k}/(1 + \hat{n}_{rt,t-k})$ and $\sum_{f=1}^5 \Delta^k h_{rt}^f := (-e_{rt} + i_{rt} - x_{rt} + g_{rt} - u_{rt})$. Then the initial productivity function (2) can be written as

$$\ln \theta_{rt}^j = \phi^j + \gamma^0 \tilde{h}_{r,t-k} + \sum_{f=1}^5 \gamma^f \Delta^k h_{rt}^f, \quad j \in \{H, L\} \quad (11)$$

In equation (11) the productivity of workers depends on their intrinsic efficiency, ϕ^j , the lagged share of high-skilled workers (adjusted by total employment growth) and the various in- and outflows of regional human capital between $t - k$ and t . As the production function (1) remains unchanged, wages for low-skilled and high-skilled

³If for example a worker with a master's degree is employed in $T - k$, unemployed in T and again employed in $T + k$ in the same region her absence from the labor market is captured in $\Delta^k H_{rt}$ but is in neither of the terms E_{rT} , I_{rT} , G_{rT} nor X_{rT} . To account for such cases U_{rt} is necessary. Note that unlike E_{rt} , I_{rt} , G_{rt} and X_{rt} U_{rt} can be negative.

workers are still given by equations (3) and (4).

With the extended productivity function, the first derivatives of the log wage equations with respect to one specific in- or outflow variable are

$$\frac{d \ln w_{rt}^L}{d \Delta^k h_{rt}^f} = (-1)^f \left(\gamma^f + \frac{\alpha}{h_{rt}(1 - h_{rt})} \right). \quad (12)$$

$$\frac{d \ln w_{rt}^H}{d \Delta^k h_{rt}^f} = (-1)^f \left(\gamma^f - \frac{1 - \alpha}{h_{rt}(1 - h_{rt})} \right) \quad (13)$$

So again productivity is influenced by a spillover effect (γ^f) and a supply effect. Note that the first term on the right-hand side of equation (12) and (13) is negative for outflows (brain drain, exits and temporary withdrawal from the labor market) and positive for inflows (brain gain and entries into the labor market). The size of the spillover effect is allowed to vary for each in- and outflow. On the one hand, an incoming migrant could increase the local diversity pool and therefore generate particularly large spillover effects. On the other hand, knowledge exchange is based on social networks. Assuming that incoming workers find comparable small networks at the beginning and outgoing workers leave comparable large networks, effects induced by brain gain might be smaller than effects generated by brain drain.

The interpretation of equation (12) and (13) follows the same logic as for equation (5) and (6). Brain drain lowers the wages of low-skilled workers. Due to the competing effects of human capital externalities and imperfect substitution, the outcome for high-skilled workers is theoretically ambiguous. It is straightforward to derive the implications of brain gain i_{rt} , labor market entries g_{rt} or exits of high-skilled workers x_{rt} . The model predicts positive effects of increases in human capital due to brain gain or entries in the labor market for low-skilled workers and negative effects for labor market exits of high-skilled workers. Furthermore, the adjusted lagged share of high-skilled workers (\tilde{h}_{rt-k}) also increases the wages of the low-skilled. In all cases the effect on wages of high-skilled individuals is uncertain due to the opposing supply and spillover effects.

Inspired by Moretti (2004), another interesting question is what happens to average wages when human capital in a region increases. The average log wage is a weighted average of wages of low-skilled and high-skilled individuals $\ln \bar{w}_{rt} = h_{rt} \ln w_{rt}^H + (1 - h_{rt}) \ln w_{rt}^L$. Consider the special case when there are no human capital spillovers ($\gamma = 0$). Then it can be shown that average wages in a region increase with a rising share of high-skilled workers if $\alpha > h_{rt}$. Hence regional average wages increase as long as the proportion of output earned by high-skilled workers exceeds the share of high-skilled workers. In our dataset the mean of h_{rt} for German counties is 0.09 in 2010. The presence of human capital spillovers weakens the condition

$\alpha > h_{rt}$. Hence even for lower levels of the production elasticity of high-skilled workers, α , average wages rise with an increasing share of high-skilled workers. The same result holds with brain gain or labor market entries of high-skilled workers.

2.2 Econometric Approach

Theoretically we derived a relationship between regional human capital and wages. We also established a link between the change of human capital between two periods and earnings. Finally we also analyzed the effects of brain drain, brain gain, entries of young high-skilled workers into the labor market and exits of elderly high-skilled workers from the labor market on wages. To check these relationships empirically, the further analysis is based on three variants of an econometric approach.

The first model is similar to that used in [Moretti \(2004\)](#). The Mincerian wage equation for an individual i living in region r at time t is

$$\ln w_{irt}^j = \eta^j h_{rt} + X_{it}\alpha^j + Z_{rt}\beta^j + \delta_i^j + \delta_r^j + \delta_t^j + \delta_s^j + \epsilon_{irt}^j, \quad j \in \{H, L\} \quad (14)$$

Here X_{it} is a row vector of relevant labor market characteristics of the individual worker and the workplace. It contains information on age, gender, education, experience, tenure, nationality, occupation and firm size. The vector Z_{rt} contains region characteristics including population density and the unemployment rate. As in [Heuermann \(2011\)](#) it also includes the number of hotel beds and land prices. The former serves as a proxy for regional amenities, the latter as a proxy for the regional price level. The large panel data set used in our empirical analysis allow us to include in equation (14) fixed effects of the individual, δ_i , the region, δ_r , the time period, δ_t , and the industry, δ_s .

In the second model we differentiate between incumbent high-skilled workers and newcomers because their effect on the regional spillover effects might vary. We therefore decompose the share of high-skilled workers h_{rt} into its lagged value h_{rt-k} and the difference between the current and the lagged value, $\Delta^k h_{rt}$:

$$\ln w_{irt}^j = \eta_0^j h_{r,t-k} + \eta_1^j \Delta^k h_{rt} + X_{it}\alpha^j + Z_{rt}\beta^j + \delta_i^j + \delta_r^j + \delta_t^j + \delta_s^j + \epsilon_{irt}^j, \quad j \in \{H, L\}. \quad (15)$$

The remaining components of equation (15) exactly match those in equation (14).

In the intermediate model we treated any change in the level of human capital equally. Hence brain drain, brain gain, labor market entry and exit had the same quantitative impact on wages in absolute terms. However, as argued above, there are good reasons to assume that the different types of changes in the relative amount of high-skilled workers have different spillover effects. To account for such differences

we allow for different coefficients for the varying changes in human capital in the third model:

$$\ln w_{irt}^j = \eta_0^j \tilde{h}_{rt-k} + \eta_1^j e_{rt} + \eta_2^j i_{rt} + \eta_3^j g_{rt} + \eta_4^j x_{rt} + \\ + \eta_5 u_{rt} + X_{it} \alpha^j + Z_{rt} \beta^j + \delta_i^j + \delta_r^j + \delta_t^j + \delta_s^j + \epsilon_{irt}^j, \quad j \in \{H, L\}. \quad (16)$$

Here brain drain is defined as the ratio of high-skilled emigrants from region r in the period between $t - k$ and t relative to the total number of workers at time t . The definitions of the three other components that describe the change in human capital over time follow the same logic.

Entries and exits of high-skilled workers respectively are the ratio of high-skilled individuals who first appeared in the labor market or who permanently left the labor market in region r between time period $t - k$ and t relative to the total number of workers in t . Additionally entrants must be of age 30 or younger and permanent leavers older than 60 years.

Including the lag of human capital in equations (15) and (16) not only is in accordance with the theoretical considerations made in the previous section, it also accounts for empirical findings suggesting a relationship between the local intensity of human capital and its growth. In the US, the skill composition of regions seems to follow a divergence process, meaning the gap between skilled and low-skilled places becomes larger over time (Berry and Glaeser 2005). Additionally Waldorf (2009) finds that well educated regions attract on average better educated migrants than less educated areas. Contrary to the findings for the US, Südekum (2008) detects a convergence process of the skill distribution across German counties. In any case, the regional level of human capital probably exerts an influence on the future growth of human capital. So estimating the effects of changes in human capital or brain drain without the (lagged) level of human capital might lead to omitted variable bias.

In all models we include individual, regional, industry and time fixed effects. Thus we are able to control for unobserved heterogeneity which is constant in these dimensions. However, one concern in the literature on human capital externalities is the endogeneity of the human capital variables. (e.g. Moretti 2004; Heuermann 2011; Bratti and Leombruni 2011). For instance, a high-wage region might attract high-skilled workers. Typically an instrument variable approach is needed to deal with this problem. Since there are up to four potentially endogenous variables in the model (brain gain, brain drain, entries and exits of high-skilled workers), we experiment with different specifications and instruments. We modify equation (16) by dropping three of the four variables of interest and use instruments that fulfill

certain requirements that allow for such a modification. One requirement on the instruments is that they are highly correlated with the endogenous variable remaining in the model (brain drain or brain gain). Additionally, the instrument must not be correlated with the error term and thus not be related to the dropped variables. These assumption can be tested through separately regressing the instruments on all four variables of interest. The instrument variable we use for brain gain is the eight year lagged number of grammar schools within 50 kilometers around a region. On average a higher number of grammar schools within a certain radius should be positively related to the future in-migration of high-skilled workers because places embedded in areas with many grammar schools have a good chance to attract some of their graduates in the future. In addition we use the occurrence of mass-layoffs in a region as an instrument for brain drain. If the number of mass-layoffs within a county increases, also the amount of out-migrating high-skilled workers should go up.

3 Data and Descriptive Statistics

3.1 Data Description

The main dataset used in the following analysis is the 'Sample of Integrated Labor Market Biographies' (SIAB) as provided by the Institute of Employment Research, Nuremberg (IAB). It contains information about a 2% sample of all employees subject to social security. Not included are self-employed workers, public servants and students enrolled in universities or technical colleges. The source contains data on wage, age, education and further personal characteristics. The information on earnings is highly reliable because employers may face legal sanctions in case of misreporting. Applying a method suggested by [Eberle et al. \(2013\)](#) the data set is transferred into panel structure only featuring the main spell of each worker on 30 June every year. We exclude part-time workers, apprentices and a small amount of employees who exclusively work at home. Furthermore we only consider workers aged 18 to 64 and delete observations with missing data in key variables. In Germany there is a contribution assessment ceiling and thus earnings are top coded. Top coding affects less than 10% of the observations. We use an imputation method proposed by [Gartner \(2005\)](#) to correct the affected records considering individual and firm characteristics. Daily wages are deflated by a general price index using 2010 as the base year. Applying a simplified version of the procedure suggested by [Fitzenberger et al. \(2005\)](#), missings in the education variable are supplemented if possibly.

We distinguish between three skill groups: low, medium and high. The first

group contains workers without a vocational training. In the medium skill group are employees with a completed vocational training. Workers with a degree from a university or technical college are considered highly skilled. We define the local share of high-skilled workers as the amount of high-skilled employees divided by the total amount of workers in a region. Occupations are classified based on [Schimpl-Neimanns \(2003\)](#).

The IAB also provides information on the size, the industry and the location of establishments (IAB-BHP)⁴. In the data the industry variable is already coded in a time-consistent manner through a method described by [Eberle et al. \(2014\)](#). However in accordance with information from the German Federal Statistical Office the 3-digit coded industries are transferred into a 1-digit system ([Statistisches Bundesamt, Wiesbaden 2003](#)).

Regional information in our analysis refers to the work place of individuals, not their place of residence. Additionally our data contains regional characteristics for the 412 German counties ("*Landkreise und kreisfreie Städte*")⁵. The Federal Institute for Research on Building, Urban Affairs and Spatial Development supplies information on population density and amenities (INKAR). The Federal Statistical Office and the statistical offices of the *Länder* publish regional land prices (GENESIS). Data on local unemployment rates is provided by the Federal Employment Agency (BA).

Because the years shortly after the German reunification might distort our estimates, migrations, entries of young high-skilled workers into the labor market and exits of older high-skilled workers from the labor market are calculated for the years 1993 and later only. The main sample for the regression analysis is reduced to the years 1995-2010 because regional characteristics are merely available for these periods. As a result of the selection process, 5,511,459 observations for 581,243 individuals remain in the sample.

3.2 Descriptive Statistics

Table 1 presents some descriptive statistics of the key variables used in the further analysis for the year 2010. Average regional wages of full-time workers in Germany are about 93 euros per calendar day. In the western part of the country workers earn significantly more than in the East (about 98 vs 73 Euros). The mean of human capital for German counties is 9.4%, hence almost every tenth working person in an average region has a degree from a university or technical college in 2010. The

⁴For further information on the data provided by the IAB see [vom Berge et al. \(2013\)](#) and [Gruhl et al. \(2012\)](#).

⁵German counties are identical to the NUTS-3 level.

Table 1: Descriptive Statistics of Key Variables at Regional Level (NUTS-3 regions, 2010 and Changes Between 2000 and 2010)

	Daily Wage 2010	Share of High Skilled	Δ Share of High Skilled change in the time period 2000 to 2010	Brain Drain	Brain Gain	Exits of High Skilled	Entries of High Skilled
All (412 Counties)							
Mean	92.783	0.094	0.020	0.056	0.063	0.010	0.033
Min	55.491	0.011	-0.054	0.005	0.010	0.000	0.003
Max	178.833	0.345	0.115	0.231	0.265	0.066	0.111
St.Dev.	16.648	0.046	0.020	0.032	0.034	0.009	0.018
West (325 Counties)							
Mean	98.172	0.091	0.024	0.053	0.062	0.007	0.034
Min	69.334	0.011	-0.022	0.005	0.010	0.000	0.003
Max	178.833	0.345	0.115	0.231	0.265	0.032	0.111
St.Dev.	13.984	0.047	0.018	0.033	0.035	0.005	0.018
East (87 Counties)							
Mean	72.653	0.104	0.002	0.059	0.063	0.021	0.027
Min	55.491	0.049	-0.054	0.018	0.012	0.004	0.006
Max	97.223	0.255	0.054	0.147	0.159	0.066	0.090
St.Dev.	8.252	0.044	0.019	0.027	0.029	0.010	0.016

Notes: Daily wage and the share of high-skilled are calculated for 2010; all other variables are related to the time span 2000 to 2010; Source: own calculations using IAB-SIAB and IAB-BHP data.

variation between counties is large and ranges from a minimum of 1% in some peripheral rural regions to a maximum of 35% in Erlangen city. The former advantage of the East in formal education on the level of high-skilled has remarkably shrunk between 2000 and 2010. Whereas the average share of high-skilled workers in the West rose by more than two percentage points, it remained almost constant in the East. Yet, in 2010 the average level of human capital in eastern German regions still exceeds the according figure in western Germany by 1 percentage point. The reason is historical. Until the early 1970s, the former German Democratic Republic (GDR) had notably more first-year students than the Federal Republic of Germany (FRG) in relation to the population ([Baumert et al. 1994](#)). Workers who started studying before this time are still present in our dataset and therefore raise the share of high-skilled workers in the eastern part of the country.

From 2000 to 2010 the average brain drain for all 412 German counties is 0.056. Hence within ten years the average county experienced 5.6 out-migrations of high-skilled workers per 100 workers. The standard deviation of this variable is about 0.03. Average brain gain in German regions is 6.2 percent and hence slightly exceeds the average brain drain.⁶ Brain drain and brain gain range from values below 1

⁶Note that the average brain drain and brain gain would be equal if all counties had the same amount of workers in 2010.

percent to values well above 20 percent. Hence there are huge differences in the dynamic changes of human capital between counties. In the eastern and western part of the country the means of both variables are similar but the variation is somewhat larger in the West. The number of high-skilled workers leaving the labor market is considerably higher in the East relative to the West. This can be explained by the greater share of high-skilled individuals among elderly workers in the East. Again, this is due to a higher proportion of first-year students in the former GDR than in the FRG in the time before 1970 (Baumert et al. 1994). By contrast, the proportion of skilled agents entering the labor market is larger in the western part of the country.

In theory we established a link between regional wages and the share of high-skilled workers. Plotting these two variables against each other gives a first impression of this relationship. The upper part of Figure 1 suggests a positive correlation between average wages and human capital. Without controlling for any other factors, wages seem to be higher in better educated places. Albeit both linear fitted lines in Figure 1 are increasing, the line for Western German counties is steeper. Note the marked wage gap between the two parts of the country, whereas the dispersion of human capital is not that different. In the bottom part of the figure the difference between the share of high-skilled workers in 2010 and 2000 is illustrated. The change in human capital is larger for counties with greater shares of high-skilled workers. Only two regions with human capital levels above 15 percent in 2010 experienced declines. The amount of counties with declining human capital is distinctively larger in East Germany. For Germany as a whole the correlation coefficient of regional mean wages and the change in human capital is 0.65.

Figure 2 and 3 give a more reliable impression of the relationship between regional human capital and wages. In both graphs the regional mean of the residuals from a wage equation is plotted against the regional share of high-skilled workers. These residuals represent the part of wages that cannot be explained by the usual factors. In Figure 2 we see a positive correlation between unexplained wages of low-high-skilled individuals and the local share of high-skilled workers. Although less pronounced, the relationship is also visible for high-skilled individuals as shown in Figure 3. Hence even after controlling for individual, industry and regional characteristics the descriptive evidence suggest that workers earn more in places with higher human capital intensity.

Figure 4 contains information on the distribution of brain drain and brain gain. Remarkably there is a clear positive correlation between the two variables. Counties facing a large (small) brain drain typically are also facing a large (small) brain gain. Most observations are off the 45-degree-line. Thus net migration of high-skilled

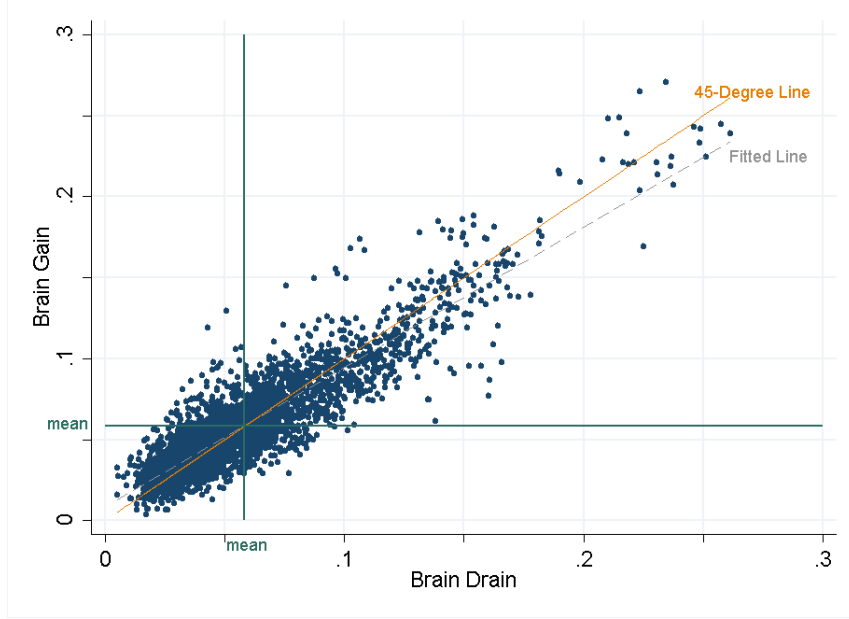


Figure 1: Human Capital and Wages (2010)

workers is usually positive or negative within a region.

4 Econometric Analysis

4.1 Estimation of the Standard Model

The first set of estimates summarized in Table 2 is based on equation (14). The underlying model is similar to the specification in Moretti (2004). Columns (1) and (2) present estimation results for all skill groups in the entire country. As suggested in the previous section, the relationship between wages and human capital might differ between East and West Germany. Hence columns (3) and (4) display separate regression outputs for the two parts of the country. In theory we also derived different effects of local human capital on wages for low-skilled and high-skilled workers. To account for that, the last two columns show results for individuals with low and medium education (low skilled) and individuals with high education (high skilled). Only column (1) is estimated with ordinary least squares (OLS), all other models are estimated with fixed effects panel methods. The dataset covers the years 2004 to 2010.

In general, the coefficients of the control variables meet our expectations very well. Especially in the panel regressions their magnitude does not change considerably between the different sub-samples. Experience and tenure exhibit the usual concave impact pattern on wages. Higher individual education raises wages. In line with the findings of Lehmer and Möller (2009), larger firms pay higher wages.

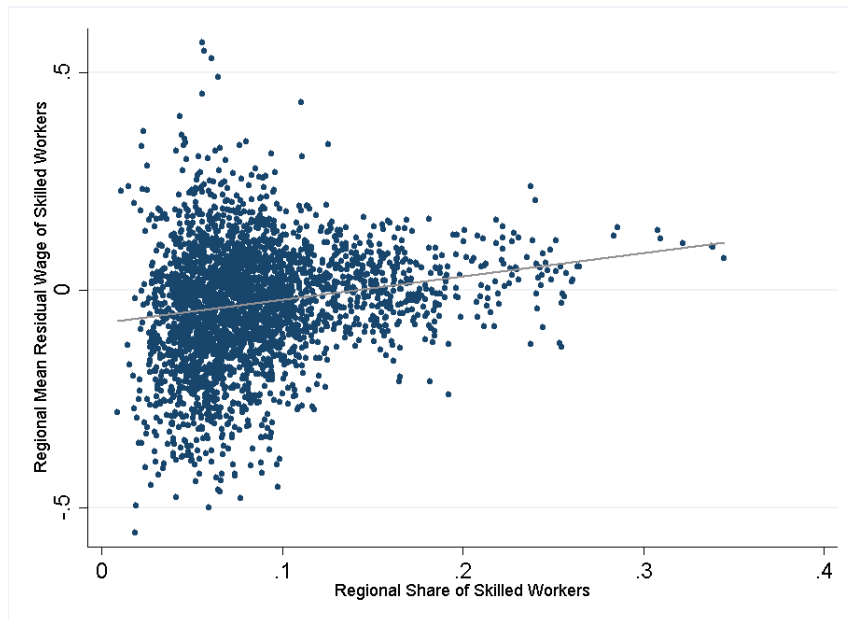


Figure 2: Human Capital and Wage Residuals (Unskilled, 2003-2010)

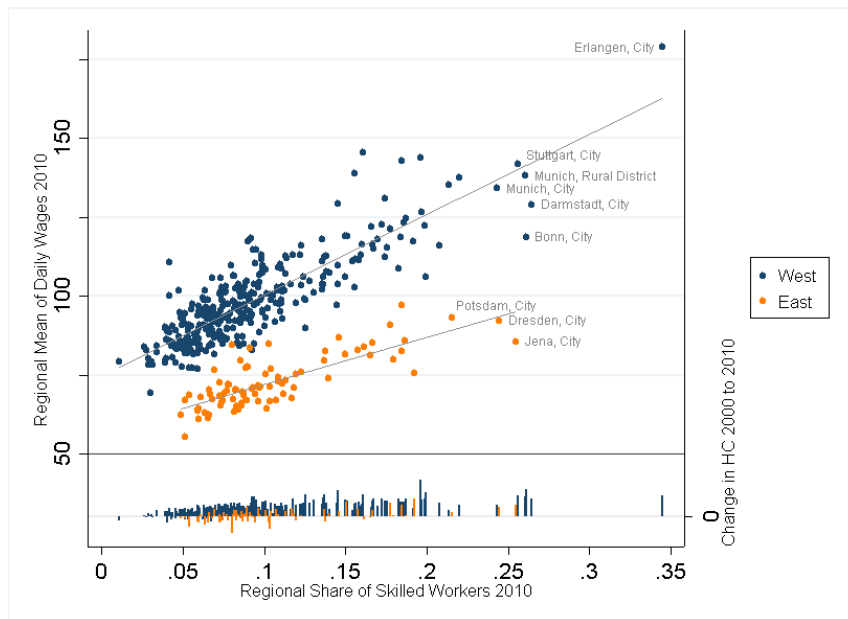


Figure 3: Human Capital and Wages Residuals (High Skilled, 2003-2010)

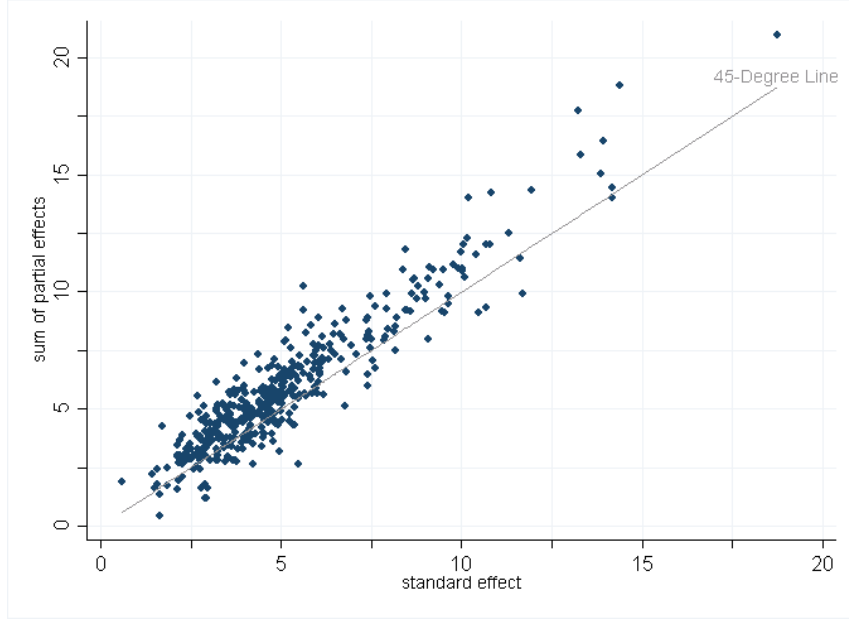


Figure 4: Regional Brain Drain and Brain Gain (2003-2010)

Other things being equal, wages are also higher in more densely populated areas. Nominal wages and local unemployment are significantly negatively correlated in the sub-samples for low-skilled and high-skilled workers. This is in accordance with the standard wage curve literature ([Blanchflower and Oswald 1995](#)). The sign of the proxy for amenities (number of hotel beds) is positive in all estimations. In the framework of [Roback \(1982\)](#) this indicates the presence of productive amenities. Theoretically, individuals accept lower wages in more amenable cities. By contrast, if amenities are productive, firms face lower costs in such places and thus are able to pay higher wages. The positive sign of the coefficient suggests that the latter effect is larger than the former.⁷ Also the proxy for the local price level (as indicated by land prices) is positively related to (nominal) wages. Using multiple imputation to generate regional price levels [Blien et al. \(2009\)](#) compare nominal and real wage differentials of urban and rural areas in Germany. They verify that nominal wage differentials are larger than real differentials. So in accordance with our control variable higher price levels are linked to higher wages.

As predicted in the theoretical section, the local level of human capital, measured as the share of high-skilled workers among all workers, is positively related to wages in all but one of the models. Only the estimates for eastern Germany are statistically not significant. In all other cases the according coefficients are statistically significant at least at the 5% level. In the panel specification for all observations an increase

⁷A negative sign would be a clear indication of unproductive amenities. Assuming unproductive amenities, firms are less productive in more amenable regions. So additionally to the fact that individuals accept lower wages in cities with more amenities production would also be more costly in such regions.

Table 2: OLS and Panel Estimates, Standard Model, 2004-2010

	Dependent Variable: $\ln(W_{irt})$					
	OLS All (1)	All (2)	West (3)	East (4)	Low skilled (5)	High skilled (6)
Regional Share of High Skilled	0.366*** (8.90)	0.294*** (10.47)	0.334*** (11.05)	0.083 (0.98)	0.223*** (7.81)	0.218** (2.31)
Age	0.012*** (21.53)	0.002 (1.39)	0.001 (0.77)	-0.015** (-2.39)	-0.020*** (-10.98)	0.038*** (5.27)
Age ² $\times 10^3$	-0.224*** (-34.89)	-0.568*** (-67.54)	-0.570*** (-60.66)	-0.447*** (-15.62)	-0.508*** (-57.95)	-0.926*** (-29.36)
Exp.	0.031*** (84.47)	0.057*** (36.20)	0.057*** (33.10)	0.070*** (11.72)	0.071*** (42.06)	0.066*** (9.94)
Exp. ² $\times 10^3$	-0.355*** (-38.48)	-0.210*** (-22.41)	-0.192*** (-18.80)	-0.406*** (-6.00)	-0.149*** (-15.33)	-0.313*** (-8.55)
Tenure	0.018*** (86.04)	0.004*** (22.86)	0.004*** (20.54)	0.004*** (4.86)	0.003*** (19.36)	0.004*** (7.87)
Tenure ² $\times 10^3$	-0.512*** (-72.08)	-0.070*** (-10.35)	-0.063*** (-9.18)	-0.069* (-1.83)	-0.060*** (-8.73)	-0.063** (-2.36)
Voc. Training	0.156*** (93.79)	0.128*** (43.04)	0.126*** (40.50)	0.102*** (7.60)	0.087*** (27.38)	-
High Skilled	0.480*** (180.32)	0.277*** (50.01)	0.279*** (46.48)	0.202*** (8.82)	-	-
Female	-0.310*** (-210.66)	-	-	-	-	-
Foreign	-0.011*** (-5.59)	-	-	-	-	-
ln Firm Size	0.080*** (239.06)	0.042*** (76.83)	0.042*** (70.69)	0.040*** (18.78)	0.043*** (70.69)	0.027*** (19.94)
ln Pop. Dens.	0.162*** (6.52)	0.349*** (19.25)	0.401*** (19.22)	0.162*** (3.66)	0.243*** (13.12)	0.066 (1.19)
ln Unempl. $\times 10^2$	-0.174 (-0.58)	-0.053 (-0.26)	0.203 (0.94)	0.017 (1.58)	-0.461** (-2.25)	-3.70*** (-5.08)
ln Hotel Beds $\times 10^2$	0.067 (0.23)	1.120*** (5.68)	1.060*** (5.09)	1.420** (2.23)	0.996*** (5.05)	0.588 (0.77)
ln Land Price $\times 10^2$	0.090 (0.96)	0.218*** (3.57)	0.309*** (4.53)	0.421** (2.50)	0.221*** (3.57)	-0.100 (-0.47)
	Dummies	Fixed Effects				
Worker	N	Y	Y	Y	Y	Y
Occupation	Y	Y	Y	Y	Y	Y
Industry	Y	Y	Y	Y	Y	Y
Region	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
Observ. \bar{R}^2 (within)	2,791,563 0.525	2,791,563 0.095	2,417,102 0.096	255,181 0.062	2,320,340 0.086	314,569 0.069

Note: cluster corrected standard errors in parentheses: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively; in all estimated equations a constant was included (not reported); Source: own calculations using IAB-SIAB, IAB-BHP, INKAR, GENESIS and BA data.

of the local share of high-skilled workers by one percentage point is associated with a 0.3% increase in wages (column 2). Separate point estimates for low-skilled and high-skilled workers are slightly smaller (column 5 and 6).

The coefficient for all observations is about 0.7 percentage points lower than those calculated by [Moretti \(2004\)](#) with fixed effects regressions. Comparing the two skill groups we find very similar effects for low-skilled and high-skilled workers. In theory we derived a positive human capital spillover effect for both groups and a positive (negative) supply effect for low-skilled (high-skilled) individuals. Therefore low-skilled workers should gain more from higher human capital intensity than high-skilled workers. For the US [Moretti \(2004\)](#) finds evidence for the hypothesis. By contrast, estimates by [Heuermann \(2011\)](#) reveal larger effects for high-skilled agents in a similar regression approach with data for Western Germany. It is argued that the size of the spillover might vary by education group (see, e.g. [Bratti and Leombruni \(2011\)](#)). As shown in our theoretical model, however, differences in the extent of the human capital externalities of different skill groups are not able to explain a higher positive effect of the high-skilled workers if the underlying production technique is of Cobb-Douglas type. Hence to reconcile the theoretical framework with the empirical evidence in the German case, a more general framework for the production technology is required.

4.2 Models with Decomposed Human Capital

The empirical examination of the standard model set the stage for the modified versions with decomposed human capital. Hence in this subsection estimation results for equation (15) and (16) are given. First, we analyze the model with the difference between the current and the lagged share of high-skilled workers ($\Delta^k h_{rt}$) and then we turn to the estimates including brain drain, brain gain, high-skilled entries and exits. Again, we distinguish between estimates for all observations and for the subsamples East/West and high-skilled/low-skilled. In these estimations the regional level of human capital is introduced with a lag of $k = 10$ years. Also $\Delta^k h_{rt}$, brain drain, brain gain and so on are considered for a ten-year period. This limits the analysis to the years 2004 to 2010. The 10-year time span is chosen under the tradeoff between a reasonable large time horizon for brain drain (and so on) to unfold effects on wages and a feasible number of years left for the regressions. Nonetheless choosing $k = 10$ is to some extent arbitrary. Later on in the robustness checks we will discuss results for smaller levels of k .

Table 3 presents estimation results for equation (15). Compared with the regressions made in the previous subsection, the coefficients of the control variables are very similar. The lagged level of human capital positively affects regional wages

in all subgroups expect for East Germany and high-skilled workers. The OLS and the panel estimates for all observations return comparable results for the variable $\Delta^{10}h_{rt}$, which indicates the absolute increase in regional human capital (columns 1 and 2). According to column 2 an increase of the share of high-skilled by one percentage point over the last ten years is accompanied by wage gains of 0.2 percent for individuals living in that region. The coefficient indicating the relationship between the incumbent skilled workforce and regional earnings is larger. Limiting the view to Western German counties, the effect is only slightly larger (column 3). Changes of local human capital intensity within the previous ten years affect low-high-skilled individuals (column 5). For high-skilled individuals and workers in East Germany the coefficient is statistically not significantly different from zero (column 4). All in all, the results support the implications of the intermediate model.

Now we turn to models described by equation (16), which include brain drain, brain gain, high-skilled exits and entries. The according estimation results are summarized in Table 4. The coefficients for the control variables in these estimates are very similar to those in the standard model and in various cases almost identical to those in Table 3. With few exceptions the lagged level of human capital (adjusted by total employment growth) is positively related to wages. Only in the sub-sample for East Germany and high-skilled workers the coefficient is statistically not significant.

The estimated effects of brain drain, brain gain and high-skilled exits and entries meet our expectations in most of the estimates. Only for those sub-samples with a relatively small number of observations, the coefficients are statistically not significant (for East Germany and high-skilled workers). According to the other estimates, brain drain lowers wages. The size of the corresponding coefficient for West Germany is -0.3 (column 3). Hence the emigration of one skilled worker per 100 workers within ten years – i.e. a brain drain of 0.01 – is associated with a reduction of regional wages by 0.3%. As presented in Table 1, the average brain drain for German counties between 2000 and 2010 is 0.06. According to our estimates, this is related to regional wage reductions of 1.8%. In the case of low-skilled workers the corresponding coefficient is -0.2 and thus smaller than the coefficient for high-skilled workers (column 5 and 6).

In all panel estimates the effect size of brain gain and brain drain are very similar. So within the time horizon under consideration, regional wages are equally related to skilled people leaving or coming to a certain region. For all observations an immigration of one skilled person per 100 workers within ten years is connected to wage gains of 0.3% (column 2). The effect is somewhat larger for Western Germany alone and statistically not significant for Eastern German counties. The coefficient positive and statistically significant for low-skilled workers but insignificant for high-

Table 3: OLS and Panel Estimates, Intermediate Model with Decomposed Human Capital, 2004-2010

	Dependent Variable: $\ln(W_{irt})$					
	OLS	Fixed Effects Panel Model				
	All (1)	All (2)	West (3)	East (4)	Low skilled (5)	High skilled (6)
$h_{r,t-10}$	0.417*** (7.09)	0.399*** (10.19)	0.496*** (11.58)	0.065 (0.53)	0.287*** (7.23)	0.070 (0.54)
$\Delta^{10}h_{r,t}$	0.285*** (6.37)	0.198*** (6.61)	0.228*** (7.06)	0.023 (0.26)	0.164*** (5.40)	0.133 (1.30)
Age	0.012***	0.010***	0.009***	-0.014**	-0.014***	0.045***
Age ² $\times 10^3$	-0.222***	-0.557***	-0.563***	-0.425***	-0.493***	-0.927***
Exp.	0.031***	0.052***	0.053***	0.072***	0.068***	0.061***
Exp. ² $\times 10^3$	-0.364***	-0.272***	-0.250***	-0.489***	-0.211***	-0.396***
Tenure	0.018***	0.003***	0.003***	0.004***	0.003***	0.004***
Tenure ² $\times 10^3$	-0.511***	-0.060***	-0.051***	-0.078*	-0.005***	-0.005
Voc. Train.	0.156***	0.124***	0.123***	0.105***	0.084***	-
High-Skilled	0.481***	0.266***	0.266***	0.195***	-	-
Female	-0.310***	-	-	-	-	-
Foreign	-0.012***	-	-	-	-	-
ln Firm Size	0.081***	0.041***	0.041***	0.040***	0.043***	0.027***
ln Popul. Dens.	0.124***	0.320***	0.338***	0.185***	0.246***	0.076
ln Unempl. $\times 10^2$	-0.800***	-0.639***	-0.352	1.16	-0.877***	-3.93***
ln Hotel Beds $\times 10^2$	0.603*	1.26***	1.04***	1.55**	1.11***	0.827
ln Land Price $\times 10^2$	0.102	0.170***	0.242***	0.328**	0.188***	-0.149
	Dummies	Fixed Effects				
Worker	N	Y	Y	Y	Y	Y
Occupation	Y	Y	Y	Y	Y	Y
Industry	Y	Y	Y	Y	Y	Y
Region	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
Observ.	2,467,803	2,467,803	2,131,384	232,256	2,045,884	281,856
\bar{R}^2 (within)	0.526	0.091	0.091	0.062	0.081	0.065

Notes: See Table 2; standard errors for control variables are omitted; Source: own calculations using IAB-SIAB, IAB-BHP, INKAR, GENESIS and BA data.

skilled individuals. According to the theoretical model, for high-skilled workers, the insignificant coefficient for brain gain could imply that the neoclassical supply effect and the effects from human capital spillovers caused by skilled immigrants level up within this time-horizon.

Entries of young high-skilled workers into the labor market and exits of elderly high-skilled workers from the labor market also influence wages. The coefficient for exits are somewhat larger than those for brain drain and brain gain. On the one hand, the panel estimates in column 2 suggest 0.3% higher wages in regions where proportional to 100 workers in year t one skilled worker entered the labor market between $t - 10$ and t . On the other hand, one retiring skilled worker per 100 workers is associated with average regional wage depressions of 0.5%. The large coefficient for elderly workers leaving the labor market might be rooted in the possibly great amount of people they know and share their huge experience with. For younger workers, to some extent, positive externalities might be caused by new (non-experience based) ideas, typically associated with this age group. However, these results should be interpreted with some caution. The literature examining the relationship between age and innovative performance is far away from a clear consensus. Technical issues as well as pronounced differences in industries and tasks make it difficult to draw general conclusions. Depending on the observation group and technique there are clues that young or old workers are more innovative (see [Frosch 2011](#) for a summary of the literature).

In all estimates the coefficient of the unexplained term u_{rt} , which accounts for temporal absence from the labor market, is statistically not significant on the 5% level.

To sum up, the empirical results fit the theoretical model rather well. Brain drain is negatively related to wages in all observations. Furthermore brain gain is positively linked to earnings in most estimates. Also the coefficients of entries of young high-skilled workers into the labor market and exits of elderly high-skilled workers from the labor market meet our expectations. All coefficients are of reasonable size.

4.3 Robustness Checks

4.3.1 Different Time Intervals

In this section we describe three robustness checks. So far we considered brain drain, brain gain and so on for a time span of ten years ($k = 10$). Choosing k to be exactly this long is to some extent arbitrary. Therefore [Table 5](#) presents regression coefficients for selected variables and different levels of k for Western Germany. The underlying regression models exactly match the panel model presented in [Table 4](#),

Table 4: OLS and Panel Estimates, Model with Decomposed Human Capital, 2004-2010

	Dependent Variable: $\ln(W_{irt})$					
	OLS All (1)	All (2)	West (3)	East (4)	Low skilled (5)	High skilled (6)
$h_{r,t-10}/(1 + \hat{n}_{rt})$	0.264*** (4.59)	0.164*** (4.32)	0.297*** (6.93)	-0.108 (-1.03)	0.116*** (3.02)	-0.096 (-0.73)
Brain Drain	-0.017 (-0.24)	-0.279*** (-5.90)	-0.293*** (-5.79)	-0.174 (-1.32)	-0.177*** (-3.70)	-0.314** (-2.02)
Brain Gain	0.494*** (7.74)	0.272*** (6.39)	0.314*** (6.65)	0.164 (1.38)	0.224*** (5.12)	0.082 (0.57)
Entries	0.135 (1.48)	0.329*** (5.38)	0.363*** (5.64)	0.160 (0.78)	0.244*** (3.96)	0.333 (1.59)
Exits	-0.960*** (-4.96)	-0.471*** (-3.64)	-0.688*** (-4.32)	0.119 (0.50)	-0.443*** (-3.38)	-0.698 (-1.60)
Others (u_{rt})	0.095 (1.57)	0.050 (1.24)	0.067 (1.53)	-0.129 (-1.32)	0.070* (1.74)	-0.027 (-0.19)
Age	0.012***	0.010***	0.009***	-0.015**	-0.014***	0.046***
Age ² $\times 10^3$	-0.222***	-0.557***	-0.563***	-0.426***	-0.493***	-0.943***
Exp.	0.031***	0.052***	0.053***	0.072***	0.068***	0.061***
Exp. ² $\times 10^3$	-0.365***	-0.272***	-0.250***	-0.484***	-0.211***	-0.380***
Tenure	0.018***	0.003***	0.003***	0.004***	0.003***	0.004***
Tenure ² $\times 10^3$	-0.511***	-0.059***	-0.051***	-0.079*	-0.050***	-0.049
Voc. Training	0.156***	0.124***	0.123***	0.105***	0.084***	-
High-Skilled	0.481***	0.266***	0.266***	0.195***	-	-
Female	-0.310***	-	-	-	-	-
Foreign	-0.012***	-	-	-	-	-
ln Firm Size	0.081***	0.041***	0.041***	0.040***	0.043***	0.027***
ln Popul. Dens.	0.088***	0.336***	0.349***	0.173***	0.259***	0.079
ln Unempl. $\times 10^2$	-1.24***	-0.704***	-0.468**	1.24	-0.934***	-3.71***
ln Hotel Beds $\times 10^2$	0.785**	1.28***	1.11***	1.50**	1.12***	0.504
ln Land Price $\times 10^2$	0.124	0.155**	0.228***	0.328**	0.174***	-0.233
	Dummies	Fixed Effects				
Worker	N	Y	Y	Y	Y	Y
Occupation	Y	Y	Y	Y	Y	Y
Industry	Y	Y	Y	Y	Y	Y
Region	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
Observ.	2,791,563	2,791,563	2,417,102	255,181	2,320,340	314,569
\bar{R}^2 (within)	0.525	0.095	0.096	0.062	0.086	0.069

Notes: See Table 2; standard errors for control variables are omitted; Source: own calculations using IAB-SIAB, IAB-BHP, INKAR, GENESIS and BA data.

column 3. The only difference is the time span k , which varies in every row. For the sake of clarity Table 5 only contains the variables of interest. As one can see in the table the effect size of the lagged level of human capital (adjusted by total employment growth) remains relatively stable in the different estimates.

The index k indicates for how long back we consider brain drain, brain gain and so on. As an example for $k = 3$ the variable brain drain contains all the emigrations of high-skilled workers that took place in $t-2$, $t-1$ and t . There are reasons why the influence of brain drain (and brain gain, skilled exits and entries) on wages should be larger for greater levels of k . The further back we lag the level of human capital, the less important it becomes. Simultaneously brain drain, brain gain and so on become more important because they reflect more and more of the actual level of human capital in a region. For an infinite large time horizon the level effect of human capital should vanish and all the explanation power should be summarized in brain drain, brain gain and so on. Another reason is that changes in human capital need time to influence earnings. Wages might react quickly to the supply effects described in the theoretical chapter, but human capital spillovers probably need some time to raise productivity and in turn lead to higher wages. Even if human capital externalities would immediately increase the productivity of locals after someone moved to a certain area, it takes some time until their wages capture these productivity gains. Empirically [Lehmer and Möller \(2009\)](#) find evidence for such wage growth effects. They analyze earnings of workers who move from rural to urban environments and find small and insignificant wage effects immediately after the relocation but large significant effects in the periods afterwards. They contribute these delayed wage gains to human capital externalities, which are particularly present in urban areas. So immigrants gain from human capital externalities only after some time. The same should be true for residents in this analysis. Since in our model larger levels of k mean that more migrations, entries and exits that took place further ago are captured in the variables of interest, the size of the according effects should be larger for greater levels of k . Thirdly, if we look at very small time horizons wage effects might just be too small to be measurable.

Another issue is the presence of temporal labor market shocks. In the approach without instrumental variables we do control for this problem. If for example a region experiences wage gains and a rise in skilled migrations due to some shock, the regression coefficient for brain gain becomes larger. This effect should be particularly noticeable if we look at short time horizons. So contrary to the arguments above, temporal labor market shocks especially boost the coefficients in regressions with very small values of k . The impact on coefficients in estimates with large levels of k should be smaller since most of the changes in human capital happened before the

Table 5: Regression Coefficients for Key Variables for Varying Time Spans (k)

Dependent Variable: $\ln Wage_{irt}$					
k	$h_{r,t-k}/(1 + \hat{n}_{rt})$	Brain Drain	Brain Gain	Entries	Exits
	(1)	(2)	(3)	(4)	(5)
1	0.314***	-0.165**	0.195***	0.137*	-0.774***
2	0.316***	-0.126**	0.240***	0.205***	-0.724***
3	0.292***	-0.154***	0.195***	0.378***	-0.901***
4	0.278***	-0.172***	0.154***	0.489***	-0.794***
5	0.230***	-0.254***	0.118**	0.525***	-0.701***
6	0.280***	-0.346***	0.132***	0.482***	-0.519***
7	0.360***	-0.395***	0.175***	0.366***	-0.685***
8	0.364***	-0.393***	0.224***	0.354***	-0.811***
9	0.330***	-0.315***	0.280***	0.344***	-0.796***
10	0.297***	-0.293***	0.314***	0.363***	-0.688***

Notes: The underlying regression models are identical to the panel model in Table 4 column 3 and include the same variables; only the time span k differs; number of observations: 2,131,384; ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Source: own calculations using IAB-SIAB, IAB-BHP, INKAR, GENESIS and BA data

shock took place. To sum up, there are reasons why the coefficients for brain drain, brain gain and so on should become larger for greater values of k but there is also an explanation for large coefficients for very small levels of k .

In Table 5 all regression coefficients for brain drain are negative and highly significant. This supports our estimation approach. Their size for different levels of k is in line with the considerations just explained. We see higher values for larger time horizons. All coefficients for the brain gain variable are positive and significant. And also here, we observe greater values for the largest time spans. Labor market exits of high-skilled workers negatively affect wages for all levels of k . Also young skilled people entering the labor market influence wages as expected in all estimates.

There are reasons why the effects of incoming and outgoing migration streams might be asymmetric. On the one hand, an incoming migrant could increase the local diversity pool and therefore generate particularly large spillover effects. On the other hand, knowledge exchange is based on social networks. Assuming that incoming workers find comparable small networks at the beginning and outgoing workers leave comparable large networks, effects induced by brain gain might be smaller than effects generated by brain drain. This could be an explanation why, for medium time spans ($5 \leq k \leq 8$), the coefficient for brain drain is larger than for brain gain. For larger time horizons, there newcomers probably became integrated, the coefficients become more similar.

Overall the robustness check supports our estimation approach. All coefficients

are significant and exhibit the expected sign.

4.3.2 An Instrumental Variable Approach

One concern in the literature on human capital externalities is the endogeneity of the human capital variables. (e.g. [Moretti 2004](#); [Heuermann 2011](#); [Bratti and Leombruni 2011](#)). The in- and out-migration of high-skilled workers could be related to time-varying region-specific labor market shocks. Typically an instrument variable approach is used to deal with this problem. Since there are up to four potentially endogenous variables in the model (brain gain, brain drain, entries and exits of high-skilled workers), we experiment with different specifications and instruments. We modify equation (16) by dropping three of the four variables of interest and use instruments that fulfill certain requirements that allow for such a modification. One requirement on the instruments is that they are highly correlated with the variable left in the model (brain drain or brain gain). Additionally the instrument must not be related to the dropped variables. These assumption can be tested through separately regressing the instruments on all four variables of interest. The instrument variable we use for brain gain is the eight year lagged amount of grammar schools within 50 kilometers around a region. On average, a higher amount of grammar schools within a certain radius should be positively related to the future in-migration of high-skilled workers because places embedded in areas with many grammar schools have a good chance to attract some of their graduates in the future. In addition we use the occurrence of mass-layoffs in a region as an instrument for brain drain. If the number of mass-layoffs within a county increases, also the amount of out-migrating high-skilled workers should go up.

Experimental instrumental variable estimates for brain gain in a model based on equation (16) without brain drain, entries and exits of high-skilled workers, and instrumental variable estimates for brain drain (without brain gain, entries and exits of high-skilled workers) support the results presented so far. The estimated coefficients are even larger than in the simple OLS case, suggesting that time-varying region-specific labor market shocks do not bias our estimates upwards.

4.3.3 Comparing the Model with Brain Gain and Brain Drain with the Standard Model

The motivation of the approach presented in this article is to split up the regional level of human capital in the wage equation into its 'components'. Thereby we implicitly assume that this decomposition is capable of replacing the actual variable properly. Thus in the last robustness check we test this assumption by comparing

Table 6: Statistics of Estimated Effects for 2010

	Observ.	Mean	St. Dev.	Minimum	Maximum
Standard Effect	412	2.761	1.362	0.313	10.137
Sum of Partial Effects	412	2.083	1.033	-0.152	7.697
Diff. in Effect Size	412	0.677	0.560	-0.729	2.861

Source: own calculations using IAB-SIAB, IAB-BHP, INKAR, GENESIS and BA data.

the results from the model with decomposed human capital (equation (16)) with the standard model (equation (14)). In order to do so we calculate wage effects for each of the 412 German counties based on the two models and compare the results.⁸ First we use the beta-coefficient of the variable human capital in table 2 to compute the associated wage effects. For this we multiply the actual level of human capital in 2010 in every region with the regression coefficient. The next step is to calculate wage effects based on the model with decomposed human capital. We use the coefficients of Table 4 column 2 and compute effects based on the lagged level of human capital, brain drain, brain gain and skilled entries and exits for all counties. Again the results are produced using the actual lagged share of high-skilled workers, brain drain, brain gain and so on for the year 2010 in each region. The term u is neglected because it is statistically not significant. Next, we separately add up these effects for each region.

Finally we compare the associated wage effects by subtracting the sum of the effects from the model based on equation (14) from the effects based on equation (16). Summary statistics of the effects and these differences are given in Table 6. In the standard model the average regional level of human capital is associated with wage gains of 2.8%. In the model with decomposed human capital the according average effect is only slightly smaller (2.1%). So both specifications produce very similar outcomes. The mean of the differences between the effects is 0.7 percentage points and thus relatively small. The positive sign indicates that in sum we tend to slightly underestimate the positive effects and/or overestimate the negative effects in the model with decomposed human capital. Plotting the two effects for the 412 German counties against each other also shows their similarity. Additionally, they are highly correlated. Since the calculated regional effects of the two models are of comparable size, also the third robustness check supports our approach.

Additionally to the robustness checks described above, various alternative specifications of the panel model with decomposed human capital (equation (16)) were estimated. Separately, in these alterations individual, firm, industry and regional control and dummy variables were left out. Qualitatively this did not change the

⁸The models cannot be interpreted causally in the strict sense.

main findings.

Overall the robustness checks support the results summarized in Table 4.

5 Conclusions

In this paper we established a theoretical link between brain drain, brain gain and wages and tested the resulting implications with data for Germany. The economic model is based on [Moretti \(2004\)](#). In his model he predicts increasing productivity due to higher shares of (high) skilled labor in the regional workforce. The extension we make here, is the decomposition of the local share of high-skilled labor into brain drain, brain gain, entries of young high-skilled workers into the labor market and exits of elderly high-skilled workers from the labor market. In theory, brain drain lowers and brain gain increases wages of low-high-skilled individuals. The effect on high-skilled workers is uncertain due to competing supply and human capital spillover effects. We also show that under certain conditions average wages decline if a region exhibits a brain drain.

Analyzing a huge panel data set we are able to confirm the theoretical implications. In separate samples for Germany as a whole, West and East Germany and differentiating between low-skilled and high-skilled workers we regress individual earnings on brain drain, brain gain and a rich set of control variables and fixed effects. We show that the emigration of one high-skilled worker per 100 workers within 10 years is associated with wage reductions of 0.3%. So with the mean of brain drain in German counties being 5.6%, the related income reduction in an average region is 1.8%. When it comes to brain gain, we find that the immigration of one skilled person per 100 workers within 10 years is also connected to wage gains of 0.3%. The wage effects caused by high-skilled workers entering the labor market and skilled people leaving the labor market are of similar size. In a separate analysis for East Germany and high-skilled workers alone we cannot find significant wage effects.

We check the robustness of our econometric model in different ways. One concern we have is an endogeneity bias due to temporal regional labor market shocks. To test whether this is a problem in our data we experiment with instrumental variable estimates. The results support our findings.

Additionally a comparison of the findings of our model, including brain drain and brain gain with the standard model, which instead includes the current share of high-skilled workers, confirms our approach.

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