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Human capital externalities vs. substitution effects as determinants of regional wages: Evidence from German micro data

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This article reconsiders the empirical evidence on regional human capital externalities using longitudinal survey data from the German Socio-Economic Panel (SOEP). It complements the empirical literature on the role of human capital for explaining regional wage differences. Based on the framework by Moretti (2004a), the impact of different proxies of regional human capital intensity on regional wages is estimated while controlling for individual productivity determinants and regional characteristics. The results are compared with the constant-composition approach by Ciccone and Peri (2006) which accounts for imperfect substitution between unskilled and skilled labor. The Mincerian panel results with level data indicate that one additional year of education has an external wage effect of 2%. However, once a difference specification is estimated, external effects are no longer present. The theoretical predictions by Ciccone and Peri (2006) that the Mincerian approach leads to an upward biased estimate cannot be verified.

Keywords: Regional wages, Education externalities, Skill composition.

JEL Classification Numbers: J2, J24, R21, R23.

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1 Introduction

Economists have identified human capital as a central determinant of economic growth and there are several channels through which human capital and productivity changes interact (Acemoglu and Autor, 2012). An important channel which may influence the pace of technological change are non-pecuniary externalities. The external effects do not operate through prices, but through ‘learning by doing’ or the exchange of ideas. These are so-called ‘knowledge activities’, often associated with firms R&D activities.¹ This study focuses on the presence of non-pecuniary externalities across German regions, and therefore helps to explain productivity differences at the regional level.

Several empirical studies have estimated the size of regional human capital externalities for Germany.² However, most studies implicitly assume a setting with perfect substitution between less-skilled and skilled labor. Motivated by this gap in the literature, this study accounts for imperfect substitution between different labor types. In addition to the Mincerian framework used by Moretti (2004a) and Heuermann (2011), it applies the constant-composition approach by Ciccone and Peri (2006) which controls for the skill composition of the work force. The right empirical identification is important because the presence of imperfect substitution effects is not a market failure, whereas, if human capital spillovers exist, a market failure may arise.³

The presence of human capital externalities in regional labor markets matters for policy makers because of several reasons. First and foremost, education subsidies are typically justified on the basis of perceived positive external effects of human capital. The opposite claim is that higher education could be an (expensive) signaling device. Secondly, it is important for economic growth policies based on endogenous growth theories which often presume the presence of human capital externalities.⁴ These can offset the dimi-

¹With the advancement of endogenous growth theory, economists formalized the notion that ‘ideas’ are very different to most other economics goods. That is, they are non-rivalrous and non-excludable. Their production is characterized by increasing returns to scale.

²For examples, (e.g. Funke and Niebuhr, 2005; Südekum, 2008, 2010; Heuermann, 2011) To the best of my knowledge, all existing studies focus on West Germany.

³A human capital externality represents a market failure. Whether this is a rationale for market intervention is an ongoing debate in the literature.

⁴In most endogenous growth models, the aggregate production function is characterized by increasing returns to scale when all externalities (θ) are accounted for. A common notation is: $Y = (AL)^{1-\alpha}k^{\alpha+\theta}$. This suggests that the ‘true’ return to capital is $\alpha + \theta > \alpha$. In other words, the

nishing returns of capital and enable sustained long-run growth. Thirdly, an alternative explanation for rising wages of skilled workers might be skill-biased technical change. Therefore, shifts in the production technology that favors skilled labor could also be responsible for the pattern observed in the data which could request policy interventions. Overall, the findings in the paper provides additional insights into the role of human capital in the regional growth process. The findings can help determining the right level of public subsidisation of education.

2 Review of the Empirical Literature

Despite their prominent theoretical role and their policy relevance, the empirical evidence on human capital externalities is contradictory. One reason might be that there is still an ongoing debate about the right framework for their detection. Generally, human capital externalities may result as a byproduct from the individual's accumulation of human capital as dynamic externalities or in the production of goods as static externalities.⁵ The first means that workers itself learn faster and acquire more human capital if surrounded by smarter workers, whereas the latter means that workers are more productive if surrounded by (better) educated workers. While there is a clear theoretical distinction between dynamic and static externalities, empirical estimations are often unable to account for the two concepts. For example, Choi (2011) argues that micro-level studies tend to focus on static externalities and often neglect dynamic aspects.

One method to estimate human capital externalities are cross-country growth regressions. This method may capture both forms of externalities (Choi, 2011). One strand of the literature was originated by Heckman and Klenow (1997), and is described by Topel (1999) and summarized by Pritchett (2006). In their approach, the aggregate effects of human capital accumulation on total output may differ from the private gains of accumulating human capital. They develop a framework to empirically estimate the size of such externalities. This so-called macro-Mincer approach compares the social returns

presence of externalities in the accumulation of capital is not captured by the neoclassical model where the returns to capital are equal to α .

⁵They may also appear as nonproduction externalities, for example, by reducing crime rates, by increasing civic participation, and by enhancing political stability. Additionally, instead of direct technological spillovers in the labor market, there may alternatively be pecuniary externalities arising from endogenous market size effects (Krugman, 1991).

of education with its private returns. The externality is the difference between wages (i.e. private returns to education) and the marginal social product of labor (i.e. social returns). A gap between the two returns indicates that external effects of education are present and have not been internalized by public subsidies or other market interventions. Based on this approach, Thönnessen and Gundlach (2013) claim that there is robust evidence in favor of a large (static) human capital externality.

Another method are micro-level Mincer regressions which use within-country data.⁶ These studies typically use Mincer wage equations with the education of co-workers or the average educational attainment of a city as additional explanatory variables on the right-hand side.⁷ For example, the seminal study by Rauch (1993) finds that an increase in average schooling by one year at the U.S. city level increases wages of workers with unchanged education by 3 to 5%. Other contributions regarding U.S. data are from Acemoglu and Angrist (2001) and Moretti (2004a). Acemoglu and Angrist (2001) use compulsory schooling laws as an instrument to identify exogenous supply changes in the years of schooling. They report no significant evidence in favor of an externality across U.S. cities and states. In contrast, Moretti (2004a) finds evidence in favor of external returns in response of an increase in the share of college graduates in U.S. cities. He uses the lagged city demographic structure and the presence of a land-grant colleges as instruments for unobservable city-specific demand shocks. Most of the subsequent empirical literature adopts the model by Moretti (2004b). More recent studies on the magnitude of human capital spillovers for the U.S. labour market are for example from Sand (2013) or Winters (2013).

In the model by Acemoglu and Angrist (2001) and Moretti (2004a), there are general equilibrium price effects because of less-than-perfect substitution between labor types.⁸ A supply increase of skilled workers always leads to a positive wage effect for less-skilled workers because of the relative scarcity of less-educated labor and possible spillovers. Both forces increase the wage of less-skilled workers. However, the impact on the wage of skilled workers is determined by two competing effects namely a negative supply

⁶A summary article on human capital externalities in cities is provided by Moretti (2004b).

⁷In the framework based on micro data, the coefficient on aggregate education can not be interpreted as a social return. However, the sum of the private return to schooling and the coefficient on aggregate education add up to the social return.

⁸This is a well established finding in the empirical labor market literature.

effect and a positive spillover effect. Only if the wages of skilled workers increase in response to a supply increase, a spillover is present because it outweighs the negative substitution effects. This is incorporated into the empirical approach by Moretti (2004a) and Heuermann (2011). Ciccone and Peri (2006) propose a framework which captures imperfect substitutability between a finite number of different educational groups, the so called constant-composition (CC) approach. Their identification of human capital externalities assumes that production requires many different, imperfectly substitutable levels of human capital. Ciccone and Peri (2006) argue that the Mincer approach, which is the prevailing approach in the literature, leads to a systematically upward biased estimate of the externality because it confounds wage changes due to substitution effects with externalities. The size of the bias is inversely related to the elasticity of substitution between more and less-skilled workers multiplied by the wage premium (Ciccone and Peri, 2006, p. 387). For a given wage premium, a higher substitution elasticity leads *ceteris paribus* to a smaller bias. This means, the magnitude of the relative wage change in response to a supply shock depends on the slope of the relative demand curve. In the case of perfect substitutability of workers, the relative demand curve is flat and relative wages do not change in response to a change in the relative supply.

Most empirical studies find that in the U.S., the elasticity of substitution ranges between 1.4 and 2 (Katz and Murphy, 1992; Ciccone and Peri, 2005). The preferred estimate of Goldin and Katz (2009) for the elasticity of substitution is 1.64 for U.S. time series data from 1915 until 2005. For Germany, the estimates are mostly in a lower range compared to the U.S. labour market. The German labour market is generally characterised by a more rigid wage structure and less worker mobility. Steiner and Wagner (1998) find a substitution elasticity of about 0.5 for male workers in the manufacturing sector, whereas Möller (2000) obtains an average substitution elasticity of 1.7. Overall, it is reasonable to assume substitution elasticities ranging between 0.5 and 1.5 in Germany.⁹ Based on this *a priori* considerations, the bias of the Mincerian approach should be relatively higher for German data than for U.S. data. Ciccone and Peri (2006) assume an elasticity of substitution between college and high-school educated workers of 1.5, and their back of the envelope calculations predict that the Mincer approach has an

⁹It should be noted that the estimated substitution elasticities between unskilled and skilled labour are proxies. They usually vary substantially between different studies depending for example on the production sector analyzed, the time period, or the way skills are measured.

upward bias of approximately 6.5%. A simulation study confirms the magnitude of the theoretical considerations.¹⁰

Based on the CC-approach, Ciccone and Peri (2006) find no significant empirical evidence in favor of an externality from an increase in the average years of schooling across U.S. cities and states between 1970 and 1990. Their point estimates are around 0 at the city level and around 2% at the state level, both being insignificant. On the other hand, the widely-used Mincer approach yields that the external effect on wages of an additional year of average schooling is around 8% and is statistically significant at the 5% level. Iranzo and Peri (2009) reconsider the empirical evidence across U.S. states applying the CC-approach. They find that the external returns from an increase in average years of high school education are always below 0.5%, while an increase in college education has external effects between 3% and 9%. They argue that the external returns occurring from an increase in high school education and an increase in college education are much different. Their theoretical model is able to explain this observed empirical pattern. The model implies that below a certain education level, an increase in schooling has no external returns. Above that threshold, which is estimated to be around 12 years, education has larger social returns than private returns.

3 Theoretical Framework

Starting point is a stylized production function with two types of labor inputs. For simplicity, physical capital is omitted from the production function as it does not change the results quantitatively (Acemoglu and Angrist, 2001). Output Y is produced with a CES-production technology:

$$Y = \left((\theta_u L_u)^\rho + (\theta_s L_s)^\rho \right)^{\frac{1}{\rho}} \quad (1)$$

¹⁰Ciccone and Peri (2006) define a skilled worker as someone with at least two years of college education. They find that the education wage premium ($\frac{w_s - w_u}{w}$) between 1970 and 1990 was approximately 40%. Together with an elasticity of substitution between college and high-school educated workers of 1.5, their model predicts that imperfect substitutability adds 27% ($0.4/1.5$) to the Mincerian estimate of the external return to college educated workers. In the U.S., average schooling of white males with more than two years of college exceeds the average schooling of less-skilled workers by 4.2 years. This implies that an increase in the share of skilled workers by 24% ($1/4.2$) is equivalent to a 1-year increase in average schooling. This implies that imperfect substitutability may add 6.5% (0.27×0.24) to the Mincerian overall external return of a 1-year increase in average schooling.

where L_u is less-skilled labor and L_s is skilled labor, and θ_x is the productivity of each type of labor. If $\theta_s > \theta_u$, productivity is skill-biased. The elasticity of substitution between skilled and less-skilled labor is $\sigma = \frac{1}{(1-\rho)}$. It is assumed that ρ is less than one and can take negative values which implies that σ is a positive number. The share of skilled labor in the total workforce is denoted as $S = \frac{L_s}{L_s+L_u}$, and the share of unskilled labor is denoted as $U = 1 - S = \frac{L_u}{L_s+L_u}$, respectively. Total employment $L_s + L_u$ is normalized to 1 so that $S = L_s$ and $1 - S = L_u$.

Human capital externalities can be modeled in a general way by assuming that the productivity of worker i depends on her own productivity enhancing skills φ_i and the share of skilled workers in her region Moretti (2004a):

$$\ln \theta_i = \varphi_i + \gamma^M \left(\frac{L_s}{L_s + L_u} \right) \quad (2)$$

If $\gamma^M > 0$, there are positive spillovers emerging from the share of skilled workers. Alternatively, as shown by Acemoglu and Angrist (1999), in a competitive labour market with perfect competition where each worker is paid its marginal product in production and based on the production function (1), the wages for skilled workers, w_s , and less-skilled workers w_u , can be written as:

$$w_s = \theta_s \left[\theta_u (L_u/L_s)^{-\rho} + \theta_s \right]^{\frac{1-\rho}{\rho}} \quad (3)$$

$$w_u = \theta_u \left[\theta_u + \theta_s (L_u/L_s)^\rho \right]^{\frac{1-\rho}{\rho}} \quad (4)$$

The effects of an increase in the supply of skilled workers in a region is the derivative of total log wages with respect to S . If the sum of log wages, W , is defined as $\ln W \equiv L_u w_u + L_s w_s$, and the private return to schooling is defined as $\ln \omega = \ln w_s - \ln w_u$, differentiating $\ln W$ with respect to S leads to:

$$\frac{d \ln W}{d S} = \ln \omega + S \frac{d \ln \omega}{d S} + \frac{d \ln w_u}{d S} \quad (5)$$

In this general framework, an increase in the share of skilled workers ($\uparrow S$) has an impact on wages in three ways: firstly, it includes the private return to schooling, secondly there is a negative effect because of declining returns to schooling $\frac{d \ln \omega}{d S} < 0$, and thirdly

a positive effect reflected in the increased wages of less-skilled workers $\frac{d \ln w_u}{dS} > 0$. The second and the third term in Eq. 5 can be interpreted as an additional return to schooling beyond the private return or an externality. The expression can be further simplified so that (Acemoglu and Angrist, 1999):

$$\frac{d \ln W}{dS} = \ln \omega + \frac{1}{(1-S)^2} \frac{1}{\sigma} \zeta_u (\omega - 1) \quad (6)$$

where ζ_u denote the share of less-skilled workers in total labor costs. The second term is always positive because $\omega = \frac{w_s}{w_u} > 0$. This leads to the key result, namely that an increase in S raises total wages by more than the private return unless $\sigma = \infty$. This means that the introduction of imperfect substitution between skilled and less-skilled workers leads to positive wage effects in response to a supply increase irrespective of the presence of an externality (Ciccone and Peri, 2006). Wages of less-skilled workers always rise because the substitution effect increases their relative scarcity in addition to potential positive externalities. For skilled workers, the wage effect is undetermined. Whether it is positive or negative depends on the size of both effects, and whether the externality can overcompensate for the negative substitution effect.

4 Empirical Identification

The main identification of the externality parameter consists of a basic comparison of wages for otherwise similar workers who work in regions with different human capital levels in the labor force. For a consistent estimation, regions are supposed to be identical in all aspects except their human capital levels. In a perfect setting, workers would be randomly distributed among regions. Based on Moretti (2004a), I estimate the following baseline model:

$$\ln \omega_{i,r,t} = X_{i,t} \beta_{r,t} + \gamma HC_{r,t} + \alpha Z_{r,t} + \delta_r + \delta_t + u_{i,r,t} \quad (7)$$

where $\omega_{i,r,t}$ is the real weekly wage for individual i in region r and survey year t . X_{it} is a vector that captures the individual characteristics gender, nationality, marital status, years of schooling, tenure, tenure squared, work experience, and work experience squared. HC_{rt} represents different proxies for the regional human capital intensity.¹¹ Z_{rt} is a vector of regional labor market characteristics such as the unemployment rate, population density or number of amenities. As outlined by Moretti (2004a), the error term $u_{i,r,t}$ consists of three components:

$$u_{i,r,t} = \mu_r \theta_i + \nu_{r,t} + \epsilon_{i,r,t} \quad (8)$$

where θ_i is an unobservable component of individual human capital such as inherent ability or family background, and $\mu_{r,t}$ is a multiplier that represents the return to unobserved skills in region r . $\nu_{r,t}$ represents shocks to labor demand and supply in region r . The remaining error $\epsilon_{i,r,t}$ is i.i.d. over individuals, regions and time. The coefficient of interest is γ , which is an estimate of the average effect of regional human capital on wages after controlling for individual wage determinants. It is important to note that Eq. (7) is unable to isolate external returns of education from substitution effects. A positive and significant estimate of γ in Eq. (7) is consistent with both: a wage increase because of the presence of neoclassical substitution effects and because of spillovers from education. That is, as outlined above, a model without spillovers predicts positive wage effects from

¹¹The preferred measure is the regional share of skilled workers in the labor force, which is the prevailing measure in the literature, and the average number of R&D employees per 1.000 employees. Krueger and Lindahl (2001) stress that productivity effects from aggregate human capital more likely depend on the regional share of skilled workers than on the average level of education.

an increase of skilled workers. A major theoretical prediction is that, irrespective of the magnitude of the externality, the wage effect associated with an increase in skilled labor should be unambiguously positive for less-skilled workers (Moretti, 2004a). On the other hand, the effect on the wage of skilled workers is only positive if the spillover is large enough to compensate the negative supply effects. Therefore, by looking at the effect of an increase in the supply of skilled workers on their own wage, one can identify the presence of externalities under the assumption of perfect substitution. A positive coefficient would indicate that spillovers more than outweigh the negative substitution effects. Similar to Heuermann (2011), I replace the second term in Eq. (7) with an interaction effect, $HC_{r,t} * D^{HQ}$ and $HC_{r,t} * D^{NHQ}$, in order to estimate the impact of the regional human capital share separately by skill group.

As a second methodology for disentangling substitution effects from externalities, I compare the Mincerian approach and the CC-approach. The first step of the Mincerian approach is an individual wage regression that controls for individual wage determinants. I follow the standard Mincerian approach (Sand, 2013) with a region-time fixed effect $\alpha_{r,t}$:

$$\ln \omega_{i,r,t} = \alpha_{r,t} + X_{i,t} \beta_t + \varepsilon_{i,r,t} \quad (9)$$

The set of region-time dummies $\hat{\alpha}_{r,t}$ can be interpreted as an regression-adjusted average regional wage. Eq. (9) is estimated for the beginning and the end of the period 1997-2011 separately by region.¹² ε_{irt} is an error term that captures other unobservable factors determining the wage of a person. In the second stage, the change in the adjusted average wage, $\Delta \hat{\alpha}_r = \hat{\alpha}_{r,t+1} - \hat{\alpha}_{r,t}$, is regressed on the change in the regional human capital intensity and the change in time-varying regional characteristics $Z_{r,t}$:¹³

$$\Delta \hat{\alpha}_r = \gamma^M \Delta HC_r + \beta \Delta Z_r + u_{i,r} \quad (10)$$

The coefficient of interest γ^M reflects the strength of average human capital externalities across regions in the Mincerian framework. $u_{i,r,t}$ is an uncorrelated error term with expectation zero and constant variance. The term $\Delta HC_r = HC_{r,t} - HC_{r,t-1}$ in Eq. (10) and (11) measures the supply change of skilled workers in the work force.

¹²Similar to before, X_{it} includes gender, nationality, marital status, years of education, experience, and experience squared.

¹³In line with Ciccone and Peri (2006), the regression also includes three macro region dummies.

In the following, I describe the CC-approach which is a modified version of the above outlined two-stage Mincerian procedure. It was introduced by Ciccone and Peri (2006), and subsequently applied by Iranzo and Peri (2009). According to the authors, it yields a consistent estimate of the externality independent of the degree of substitution between different skill groups. The constant-composition wage for each region r is constructed for the beginning (t) and the end of the period ($t + 1$). This is done by multiplying the regression-adjusted wage of 8 education-experience groups with its share in the total labor force in region r in the previous period.¹⁴ The average wage at the end of the period $\hat{w}_{r,t+1}$ is calculated by weighting each group with its share at the beginning of the period. Finally, the *change* in the estimated constant-composition real wage by region is calculated as: $\Delta \ln \hat{w}_{r,t}^{cc} = \ln \hat{w}_{r,t+1} - \ln \hat{w}_{r,t}$.¹⁵ The size of the average human capital externality can be estimated by regressing the log-change of average wages assuming a constant composition of the work force on the change in the human capital level with the same time-varying regional controls as before:

$$\Delta \ln \hat{w}_{r,t} = \alpha_r + \gamma^{CC} \Delta HC_{r,t} + \alpha \Delta Z_{r,t} + \mu_{r,t} \quad (11)$$

where γ^{CC} is the coefficient of interest and $\mu_{r,t}$ is an uncorrelated error term with expectation zero and constant variance.

¹⁴ $\ln \hat{w}_{r,t} = \sum_{g=1}^{G=8} \ln \hat{w}_{g,r}(sch, exp) \cdot l_{g,r,t}$, and $\ln \hat{w}_{r,t+1} = \sum_{g=1}^{G=8} \ln \hat{w}_{g,r,t+1}(sch, exp) \cdot l_{g,r,t}$. The four education groups are: G1, ISCED category 1, 2 ('Haupt-/Realschulabschluss' or less); G2 ISCED category 3a,3b,3c ('Abitur/Equivalent'); G3, ISCED category 4a, 4b ('Meister/Techniker' or equivalent 'Fachschulabschluss'); G4 ISCED category 5a, 6 ('Fachhochschule/University/PhD'). Workers of these four groups are further divided into less or more than 20 years of work experience.

¹⁵The estimated value for $\Delta \ln \hat{w}_{r,t}^{cc}$ can be interpreted as the empirical counterpart of the percentage change in total factor productivity (TFP) (Ciccone and Peri, 2006). Based on the dual approach to growth accounting (Jorgenson and Griliches, 1967), changes in TFP are measured as the changes in (real) factor prices. If labor is the only factor of production, changes in TFP are reflected by wage changes.

4.1 Data and Descriptive Results

The main data source is the 2011 Long Beta version of the German Socio-Economic Panel (SOEP)¹⁶ The longitudinal data cover the time period from 1996 until 2011 with 16 yearly survey waves. The panel structure of the data allows for tracking a worker's employment changes over time. In comparison to Census data, the longitudinal data have less observations per region. The advantage of survey data are richer information on the individual level and more complete labor earnings data. They also cover high-income groups who are free to leave the public system and insure privately¹⁷ In addition to the longitudinal data, in order to have a larger sample size, I use data from the German Census ('Mikrozensus') from 1997 and 2011 to estimate Eq.(9), (10) and (11). The sample covers 235,518 individuals in 1997 and 230,791 individuals in 2011.

Labor market regions in the study are Regional Policy Regions ('*Raumordnungsregionen*'; henceforth ROR) which are 96 economically coherent spatial units (see appendix Table 2 for an overview). The regions sufficiently represent self-contained labor markets as they reflect workers commuting behavior, and mostly cover a core city and its surrounding periphery.¹⁸ Because of a number of country allocation reforms, a consistent assignment of the territories to a ROR is only possible from 1996 onwards.¹⁹For this reason, the empirical analysis is restricted to the period from 1996 until 2011. All variables on the individual level for the panel estimations of Equation (7), such as years of schooling, work experience and demographic characteristics are from the SOEP. The weekly wage in a given year has been calculated by dividing the monthly gross labor income by 4.2.²⁰

¹⁶The SOEP is a representative longitudinal study of private households in Germany. The questioning population are private households and their members who reach the age of 17.

¹⁷The threshold currently amounts to appr. 5.800 EUR monthly gross income. This subgroup is represented by the high-income household sample.

¹⁸The 'ROR' are defined by the Federal Office for Building and Regional Planning to differentiate areas in Germany based on their economic inter-linkages. A geographically smaller regional scale would be the county level ('*Kreise and kreisfreie Städte*') which are often comparable to NUTS III at the European level. The number of counties in Germany currently amounts to 439.

¹⁹The number of counties in Eastern Germany has been reduced from 215 counties in 1991 to 111 counties in 1996. For more information on the definition of SOEP-Geocodes (in German) see Goebel (2011), http://www.diw.de/documents/dokumentenarchiv/17/74806/ror_dokumentation.pdf.

²⁰The sample only includes individuals between 16 and 65 years of age who worked at least one week in the previous year, and have a positive wage income. Self-employed workers are included. This is a merit of survey data in comparison to census data. As proposed by Florida (2002), the 'creative

Table 1: Summary statistics, regional labor markets, 1996 and 2011

	Year	Mean	Stdv	Min	Max
Share of skilled labor	1996	6.74	2.68	2.90	14.90
	2011	9.15	2.98	4.10	18.90
R&D density	2003	9.30	8.37	0.50	45.20
	2011	10.39	8.47	0.30	43.40
Time period: 1996-2011					
GDP per worker		52.77	7.80	34.40	81.40
Population density		330.29	495.00	44.27	3878.67
Unemployment rate		9.85	4.60	2.60	24.20
Amenities		39.11	35.11	5.00	321.70
Housing supply		3.54	2.08	0.50	15.30
Building land price index		92.39	68.74	8.96	369.20

Notes: No. of regions: 96. R&D density is only available for the years 2003, 2005, 2007, 2009, and 2011. Building land prices are only available for the years 2000, 2005 and 2010. Amenities are measured as number of hotel beds per 1.000 inhabitants. Housing supply is measured as newly build apartments per 1.000 inhabitants. Source: Federal Statistical Office (BBSR, 2013).

All aggregate, regional variables such as the unemployment rate are taken from the Federal Institute for Regional Studies and Planning (‘Bundesinstitut für Bau-, Stadt- und Raumforschung’, BBSR, 2013). The summary statistics of the regional control variables are displayed in the lower half of Table 1. In line with Heuermann (2011), the supply of hotel beds is used as proxy for regional amenities. A high number of hotel beds indicates that the region is attractive for leisure or business motives. Further regional variables which account for labor demand shifts are the unemployment rate, and building activities measured by the number of completed apartments and a building price index. A high level of agglomeration facilitates the exchange of ideas and is therefore included to control for a source of increasing returns (Henderson, 1974). The regions differ substantially with regard to their degree of agglomeration, ranging from highly agglomerated cities to rural-peripheral regions. For example, the population density of Altmark in Saxony-Anhalt is 45 inhabitants per square kilometer compared to a population density of more than 500 in most of the major cities. The map in Fig. 1 illustrates the distribution of real income per worker across labor market regions in 1996. The region with the highest income in the sample is Munich with 81.4 EUR average GDP per worker, whereas most low-income regions are located in the Eastern part of Germany.

class’ which is often self-employed might contribute significantly to spillover effects.

The regional human capital intensity is measured in two different ways. Firstly, the percentage share of the employed labor force²¹ with a higher-education degree (‘höhere Fach-, Fachhoch- oder Hochschule’) is used as a proxy. This measure is also in line with the variable ‘share of college graduates’ which is used in most of the U.S. literature (Moretti, 2004a; Iranzo and Peri, 2009; Sand, 2013) and is therefore the preferred measure. It is available for the period from 1996 onwards. Secondly, the R&D density measured by the number of employees in research and development per 1.000 employees is used.²² Both statistics are published by the BBSR (2013) which collects the data from the Federal Statistical Office. As shown in Table 1, the R&D density has more variation across regions than the share of skilled workers. The density of R&D employment also takes into account whether acquired skills are employed in a way that contributes to productivity changes.²³ The share of skilled workers in 2011 ranges from 18.9% in Munich to 4.1% in Oberpfalz-Nord, with an overall sample mean of 9.15% and a standard deviation of 2.98 (see Table 1).

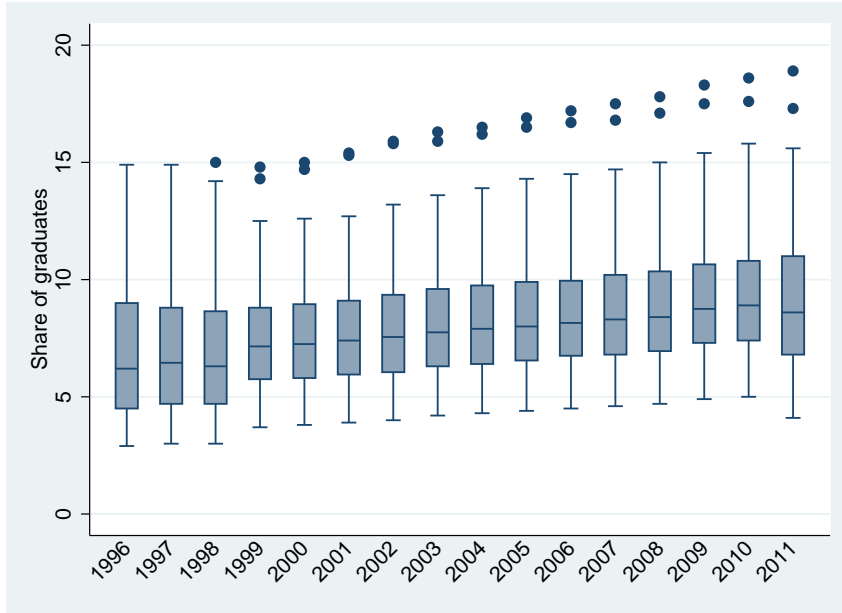
During the period under study, the supply of skilled workers has steadily increased over time. The country-wide average share of workers holding a degree from a higher education institution has increased from 7.9% in 1996 to 10.8% in 2011. Figure 1 shows the change in the distribution of skilled workers over time across the 96 labor market regions. The length of the upper whisker and the adjacent value has increased more rapidly than the lower whiskers which indicates that there is a divergence of human capital across regions over time. Highly-agglomerated areas such as the Rhein-Main area or Stuttgart which represent the upper outside values improved their human capital endowment mostly because of migration of workers. This emphasizes that the effect of the human capital share on wages might reflect non-random selection of inherently more productive workers who migrate to larger cities rather than spillover effects.

²¹The employed labor force includes all workers who are part of the public social security system (‘sozialversicherungspflichtig Beschäftigte’)

²²The regional R&D density is only available for the years 2003, 2005, 2007 and 2009. Both proxies have the drawback that self-employed and civil servants are not included.

²³Otherwise, measurement errors might result from skills that do not enter the production process (Funke and Niebuhr, 2005), such as the notorious example of the taxi driver with an academic degree.

Fig. 1: Boxplot of the distribution of highly-skilled workers across regions, change from 1996 until 2011, , $N = 96$. *Source*: own calculations, BBSR (2013).



4.2 Panel Estimation Results for German regions

Table 2 shows the estimation results for the baseline model based on Equation (7). The first column reports the pooled OLS estimates which neglects the panel structure of the data. As expected from the empirical labor literature, the private return to education is close to 8%. The coefficients for the covariates *Tenure* and *Experience* are within the expected range, with a return to education of 3%. Similar to Iranzo and Peri (2009), all specifications include three regional dummies (East, South, West, omitting North) in order to account for heterogeneity across macro regions. All regressions include time fixed effects and therefore wages are not adjusted by inflation. I include eight industry dummies based on the 1-Digit Industry code provided by the NACE to account for the sectoral composition and potential industry driven effects on the spillover. The results in Column 1 suggest that a 1 percentage point increase in the human capital share led to a 1.13% increase in average wages in the period from 1996 until 2011. In fact, the average share of graduates across labor market regions increased by 2,9% during the period under study. At the same time, the average years of education increased by 1.5 years. In other words, a 1 percentage point increase in the human capital share was equivalent to an increase in years of education by 0.5. The result in Column 1 implies

that the external return of one additional year of education is approximately 2.25%.²⁴

In the second column of Table 2, the between estimator yields similar results. The between estimator exploits the between dimension of the data by taking individual averages. It is usually less efficient than an estimator which exploits the within and between dimension of the data (Greene, 2012). When including individual fixed effects in order to control for unobserved, permanent characteristics of workers, the estimated external return is lower (0.68, s.e. 0.24) and still significant at the 5% level. This is in line with Heuermann (2011) who also finds that wage effects from aggregate human capital levels are underestimated with individual fixed effects regressions. This is likely due to supply shocks of skilled workers in already skilled cities such as Munich. As a robustness test, the private return to education is allowed to vary by region. This leaves the externality coefficient nearly unchanged. Based on a Hausman test, the null hypothesis that a random-effects model is more appropriate than a fixed-effects model is rejected.

The specifications in the first three columns are likely to have a self-selection bias because inherently more productive workers move into labor markets with higher wages according to their comparative advantage (Moretti, 2004a). For example, a worker who has moved to Cologne to work in a startup differs along some unobservable dimension from a person working at a manufacturing plant in the countryside. If unobserved individual productivity determinants are correlated with the higher human capital share, such that $cov(\theta_i, HC_{r,t}) \neq 0$, the estimate of γ is biased. In order to measure only the variation in wages of workers who did not change regions, individual-region fixed effects are added in specifications (4) and (5). The coefficient of 1.03 (s.e. 0.23) indicates that migration is not a source of bias. Specification (4) omits the industry dummies which only slightly changes the coefficients in comparison to the preferred regression with industry dummies (Column 5). All specifications include the local unemployment rate, the population density and the number of amenities in order to control for labor demand shifts. The overall finding of an externality parameter close to 1 in Table 2 is consistent with Moretti (2004a) who finds external returns based on the college graduate share of

²⁴This figure can be compared to the empirical findings based on the restricted macro-Mincer framework where the externality parameter is the wedge between the private and the social return to education (Heckman and Klenow, 1997).

0.6 - 1.2% for U.S. cities. The coefficient is somehow lower than the result of Sand (2013) who finds that in the 1980s a one percentage point increase in the college graduate share increases U.S. city-level wages by 1.84%. The estimated coefficients represent the sum of the substitution effects and the external effects. Next, in Table 3, the effect of the human capital intensity on different types of labor is estimated with an interaction effect based on (Heuermann, 2011).

Table 2: Panel estimates on the effect of an increase in the share of skilled workers 1996-2011

	(1) Pooled OLS	(2) Between estimator	(3) Individual effects	(4) Regions \times individual effects	(5) Regions \times individual effects
γ (HC-share/100)	1.125* (0.204) [0.000]	1.118* (0.127) [0.000]	0.683* (0.239) [0.004]	1.055* (0.231) [0.000]	1.027* (0.226) [0.000]
School	0.079* (0.001)	0.079* (0.001)	0.026* (0.003)	0.078* (0.002)	0.079* (0.002)
Tenure	0.015* (0.001)	0.023* (0.001)	0.004* (0.001)	0.010* (0.001)	0.010* (0.001)
Tenure ²	-0.000* (0.000)	-0.000* (0.000)	-0.000 (0.000)	-0.000* (0.000)	-0.000* (0.000)
Exp	0.027* (0.002)	0.029* (0.001)	0.045* (0.004)	0.030* (0.001)	0.030* (0.001)
Exp ²	-0.000* (0.000)	-0.001* (0.000)	-0.001* (0.000)	-0.001* (0.000)	-0.001* (0.000)
Macro region dummies					
East	-0.298* (0.029)	-0.264* (0.017)	-0.094* (0.038)	-0.296* (0.031)	-0.298* (0.032)
South	0.013 (0.019)	0.017 (0.011)	0.049 (0.040)	0.021 (0.019)	0.025 (0.019)
West	0.002 (0.018)	0.005 (0.011)	0.029 (0.038)	-0.003 (0.019)	-0.001 (0.019)
F-statistic	517.60	497.36	172.35	213.24	260.92
Hausman test p -value			0.000	0.000	0.000
Within R^2			0.14	0.31	0.32
Regional controls	YES	YES	YES	YES	YES
Industry dummies	YES	YES	YES		YES
N	95.812	95.812	95.812	95.812	95.812
N grouped		17.619	17.619	13.582	13.582

Notes: Human capital share is measured as the percentage share of highly-qualified workers in the labor force. Heteroskedasticity-robust standard errors, clustered by region, are in parentheses. p -values are reported in brackets. * denotes significance at the 5% confidence level. Year effects are included in all specifications. Reference category for the regional macro dummies is Northern Germany. Gender, nationality, marital status are included but not reported. Regional control variables are the unemployment rate, number of amenities and the population density. H_0 of the Hausman test is that the coefficients are uncorrelated which would indicate appropriateness of the random-effects estimator. The table is similar to Moretti (2004a).

The positive and significant coefficient for highly-qualified workers in Column (1) of Table 3 suggests that the external effects are sufficiently large to compensate for negative substitution effects. The main result of the panel estimations is that in the case of two skill groups the predicted negative substitution effects are empirically rejected. Column (2) and (3) display the results of the robustness checks of the preferred specification with individual-region grouped fixed effects. The estimate is higher when using only male workers, and it decreases once individual education is included in a non-linear way with 11 dummy variables for each year of education (Column 3). The magnitude of the coefficient is in line with the IV estimates of Heuermann (2011) who finds that a rise in the share of skilled workers by 1% increases wages of skilled workers by 1.8% in Western German counties for the period from 1995-2001. The estimate of the externality becomes lower (0.35, s.e.0.15) when using R&D density as a proxy for human capital (Column 5). In comparison to specification (1) which is the reduced sample estimation, the coefficient for externalities which are rooted in the R&D intensity is significantly smaller.

Table 3: Interaction effects and robustness checks for the estimations in Table 2.

	(1)	(2)	(3)	(4)	(5)
	Baseline	Males only	Non-linear schooling	Baseline red. sample	R&D intensity
All workers (HC)	1.027* (0.226)	1.137* (0.297)	0.931* (0.228)	1.296* (0.319)	0.308* (0.088)
HC * D^{HQ}	1.893* (0.265)	1.445* (0.320)	1.381* (0.332)	1.746* (0.399)	0.354* (0.147)
HC * D^{NHQ}	0.670* (0.228)	0.924* (0.311)	0.865* (0.320)	1.113* (0.320)	0.290* (0.094)
F-statistic	209.54	206.02	191.64	83.71	82.53
Within R^2	0.32	0.32	0.31	0.30	0.30
Regional controls	YES	YES	YES	YES	YES
Industry dummies	YES	YES	YES	YES	YES
N	95812	95812	95812	29831	29831
N grouped	13582	13582	13582	10480	10480

Notes: See Table 2. Column (1) is the benchmark specification from Table 2, column (5). The coefficient for male workers is estimated with an interaction effect. Gender, nationality, marital status, years of education, tenure, tenure squared, experience, experience squared are not reported. The reduced sample includes the years 2003, 2005, 2007, 2009, and 2011.

4.3 IV estimation results with Census data

According to Equations 10 and 11, it is tested whether the change in the fraction of skilled workers in a region exerts a positive effect on the change in average regional wages. A difference specification for the time period from 1997 until 2011 with the same data set is comparable to the the results of the panel estimations in Table 3 with levels. In the difference framework, a 2SLS estimation is applied to reduce a possible endogeneity bias which comes from shocks to local labor markets that increase both wages and the demand for skilled workers. For a consistent estimation, the instruments must be exogenous and relevant. Because of the county territorial reform in 1996 the 10-year lagged demographic structure cannot be used as an instrument, as done for example by Ciccone and Peri (2006).

Following the argumentation of Heuermann (2011) who uses the number of high schools ('Gymnasien') and of students attending them as instruments for the level of skilled workers, I use the share of enrolled university students in 1996 in the total population to instrument the change in the regional share of skilled workers.²⁵ Universities and technical colleges in Germany are highly decentralized and their location can be seen as an exogenous political decision unrelated to today's productivity changes. It is argued that young workers prefer to stay close to their social surrounding known from university education and later on work in the same region. This home-bias argument is supported by the low mobility rates of German workers and students (Heuermann, 2011). The size of the Wald-F-statistic (23.12) and the Kleibergen-Paap test for underidentification indicates that the instrument is sufficiently correlated with the endogenous variable.

The results in Table 4 suggest that once a difference specification is employed, external effects are no longer present. This holds for the Mincerian approach and the CC-approach. The first two columns show the results of the Mincerian approach with SOEP data according to Eq. 10. The coefficient for the change in the skill share is not statistically

²⁵Most of the instruments used in the U.S. labor market literature are not suitable for the German case. Moretti (2004a) and Ciccone and Peri (2006) use a city's lagged demographic structure and national-level changes in college completion as instruments for the change in regional college share. Iranzo and Peri (2009) use child labor and compulsory attendance laws and the presence of land-grant colleges to predict the change in years of college per worker. Sand (2013) uses immigrants 'enclaves' to predict immigration flows and thus changes in college shares. He also uses climate variables such as temperature and precipitation.

different from zero at the 5% level. As expected, the log change in aggregate employment has a positive effect on wage changes. The Mincerian estimation with Census data (Column 3 & 4, sample size: >200k individuals) also yields that there are no external effects. It is puzzling that the estimation with Census data has a much lower adjusted R^2 , and the log change in aggregate employment is no longer significant. The findings are at odds with Ciccone and Peri (2006) who find that the Mincerian approach yields a statistically significant external effect of an additional year of average schooling for the period 1970-1990. The CC-approach in Column (5) leads to insignificant results.

Table 4: OLS and 2SLS estimates of the external effect of changes in the share of high skilled workers, 1997-2011

	Dependent variable: regional change in average wages $\Delta \hat{\alpha}_r$				
	(1)	(2)	(3)	(4)	(5)
	SOEP data		Census data		
	Mincerian appr.		Mincerian appr.		CC-appr.
	OLS	2SLS	OLS	2SLS	OLS
$\Delta \text{Share HQ}$	0.004 (0.009)	-0.014 (0.020)	-0.030 (0.030)	0.013 (0.062)	-0.002 (0.059)
$\Delta \ln \text{Empl}$	0.519* (0.150)	0.624* (0.188)	0.431 (0.453)	0.177 (0.634)	-0.908 (1.609)
North	-0.008 (0.036)	-0.017 (0.035)	-0.089 (0.095)	-0.069 (0.097)	0.051 (0.094)
East	-0.112* (0.037)	-0.143* (0.048)	-0.399* (0.112)	-0.325* (0.146)	0.174 (0.185)
South	-0.005 (0.030)	-0.007 (0.029)	-0.112 (0.083)	-0.106 (0.083)	0.032 (0.082)
Adj. R^2	0.39	0.37	0.17	0.15	0.02
N Regions	96	96	96	96	96
N Workers 1997		5.519		222.888	
2011		7.393		216.728	
First-stage statistics					
Partial R^2		0.23		0.23	
Kleibergen-Paap		19.62		19.62	
KP p -value		0.00		0.00	
Wald- F -statistic		23.12		23.12	

Notes: Robust standard errors in parentheses. * denotes significance at the 5% confidence level. $\Delta \text{ShareHQ}$ is the change in the fraction of highly qualified workers, $\Delta \ln \text{Empl}$ denotes the log change in aggregate employment. Other regional control variables such as the change of the unemployment rate and the number of amenities have been omitted. The very low F-statistic and adj. R^2 reveal a misspecification problem. Wald F-statistic: robust analog of the Cragg-Donald statistic. Kleibergen-Paap is a tests for underidentification.

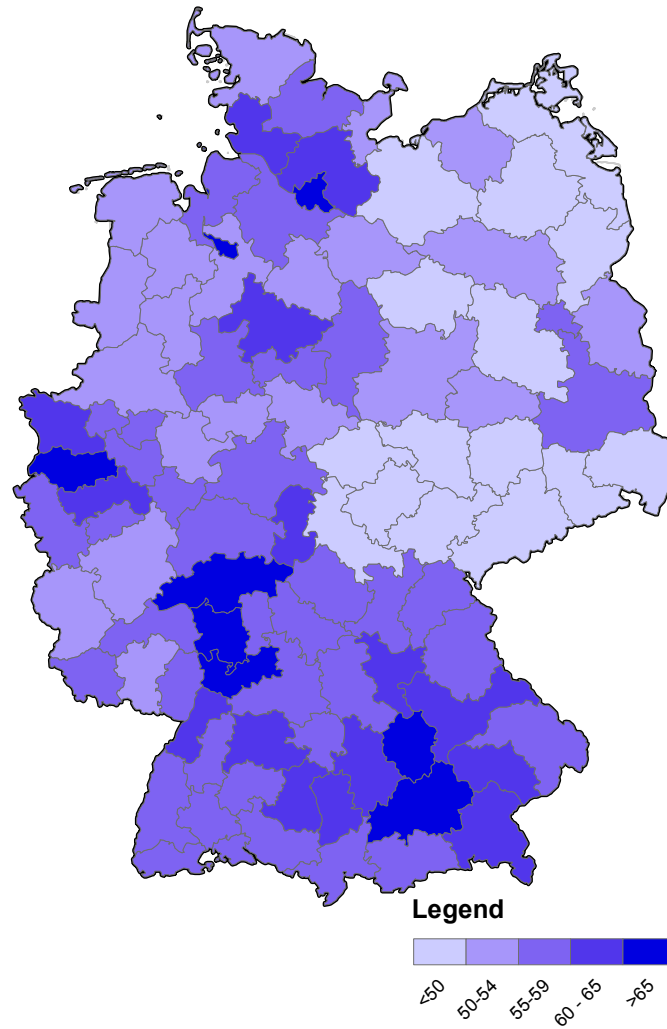
5 Conclusion

This paper investigates the link between regional human capital intensity and productivity differences across 96 German labor market regions. It explicitly addresses the role of externalities and imperfect substitutability of different types of labor. The study uses data on wages, educational attainment and other socio-demographic factors from the SOEP to estimate a panel model for the period from 1996-2011. The data on regional characteristics stem from the Federal Statistical Office. As a robustness test, the effect of regional supply changes in human capital on wages changes is also estimated with Census data from 1997 and 2011.

The paper follows the idea that the human capital stock of the workforce creates a direct non-pecuniary (technological) spillover on the productivity of each worker. Acemoglu and Angrist (1999) and Ciccone and Peri (2006) show that in a model with general equilibrium price effects and imperfect substitution between skilled and unskilled labor, there are positive wage effects in response to supply increase even in the absence of an externality. This price effect renders the externality coefficient in a simple Mincerian framework biased upwards. Therefore, Moretti (2004a) and Heuermann (2011) adjust the Mincerian approach and test for an effect of supply changes on two different types of labor. This approach is reconsidered in this article. Additionally, the constant-composition approach by Ciccone and Peri (2006) is applied which controls for the composition of eight different skill groups in the workforce.

The two main results of the paper are that firstly there is an overall positive and significant effect of the regional human capital level on wages. A one percentage point increase in the fraction of skilled workers led to a 1.9% increase in the average wages of skilled workers in the period from 1996 until 2011. This effect is robust to a number of alternative specifications. However, the endogeneity of the human capital share remains a potential source of bias. Secondly, once a difference specification is applied, which is the prevailing approach in the U.S. labor market literature, the external effects are no longer present. This holds for the adjusted Mincerian approach and the constant-composition approach. The reason could be that regions with low human capital levels have experienced relatively large gains in the skill level. A task for future research could be to resolve the contradictions between the level and the difference specification.

A Appendix



A. 1: GDP per worker across 96 labor market regions (*'Raumordnungsregionen'*), 1996,
Source: Federal Statistical Office (BBSR, 2013).

A. 2: Overview of the 96 German regions in the sample (*'Raumordnungsregionen'*). Source: BBSR, http://www.bbsr.bund.de/BBSR/DE/Raumbeobachtung/Downloads/downloads_node.html

Code	Region name	Code	Region name
101	Schleswig-Holstein Mitte	806	Neckar-Alb
102	Schleswig-Holstein Nord	807	Nordschwarzwald
103	Schleswig-Holstein Ost	808	Ostwürttemberg
104	Schleswig-Holstein Süd	809	Schwarzwald-Baar-Heuberg
105	Schleswig-Holstein Süd-West	810	Stuttgart
201	Hamburg	811	Südlicher Oberrhein
301	Braunschweig	812	Unterer Neckar
302	Bremen-Umland	901	Allgäu
303	Bremerhaven	902	Augsburg
304	Emsland	903	Bayerischer Untermain
305	Göttingen	904	Donau-Iller (BY)
306	Hamburg-Umland-Süd	905	Donau-Wald
307	Hannover	906	Industrieregion Mittelfranken
308	Hildesheim	907	Ingolstadt
309	Lüneburg	908	Landshut
310	Oldenburg	909	Main-Rhön
311	Osnabrück	910	München
312	Ost-Friesland	911	Oberfranken-Ost
313	Südheide	912	Oberfranken-West
401	Bremen	913	Oberland
501	Aachen	914	Oberpfalz-Nord
502	Arnsberg	915	Regensburg
503	Bielefeld	916	Südostoberbayern
504	Bochum/Hagen	917	Westmittelfranken
505	Bonn	918	Würzburg
506	Dortmund	1001	Saar
507	Duisburg/Essen	1101	Berlin
508	Düsseldorf	1201	Havelland-Fläming
509	Emscher-Lippe	1202	Lausitz-Spreewald
510	Köln	1203	Oderland-Spree
511	Münster	1204	Prignitz-Oberhavel
512	Paderborn	1205	Uckermark-Barnim
513	Siegen	1301	Mecklenburgische Seenplatte
601	Mittelhessen	1302	Mittleres Mecklenburg/Rostock
602	Nordhessen	1303	Vorpommern
603	Osthessen	1304	Westmecklenburg
604	Rhein-Main	1401	Oberes Elbtal/Osterzgebirge
605	Starkenburger	1402	Oberlausitz-Niederschlesien
701	Mittelrhein-Westerwald	1403	Südsachsen
702	Rheinhessen-Nahe	1404	Westsachsen
703	Rheinpfalz	1501	Altmark
704	Trier	1502	Anhalt-Bitterfeld-Wittenberg
705	Westpfalz	1503	Halle/S.
801	Bodensee-Oberschwaben	1504	Magdeburg
802	Donau-Iller (BW)	1601	Mittelthüringen
803	Franken	1602	Nordthüringen
804	Hochrhein-Bodensee	1603	Ostthüringen
805	Mittlerer Oberrhein	1604	Südthüringen

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