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The determinants of regional disparities in skill segregation – Evidence from a cross section of German regions

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Abstract:

Increasing inequality in qualification specific employment prospects characterises labour markets in most highly developed countries. Theoretical models suggest that in-plant skill segregation might matter for the polarisation of employment and wages. According to these models production technology and the educational level of the work force are important determinants of skill segregation. There are some studies that investigate the increasing in-plant skill segregation at the national level. However, since production technologies and skill structures are characterised by pronounced regional disparities, there are likely significant differences in the level of segregation between regions. But empirical evidence on corresponding regional inequalities is lacking. The objective of this analysis is to investigate regional disparities in skill segregation in Germany. Our findings point to marked disparities among German regions. Moreover, we analyse the determinants of these differences at the regional level. The results of a regression analysis indicate that the local endowment with human capital is an important determinant for the regional level of skill segregation. Furthermore, skill segregation is increasing in most areas during the period under consideration, which may lead to unfavourable labour-market conditions for low-skilled workers in corresponding regional labour markets.

Keywords: regional labour markets, skill segregation, human capital

JEL Classification: R11, J21, J24

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1 Introduction

Labour markets in most highly developed countries are characterised by increasing inequalities in qualifications-specific employment prospects. Nickel and Bell (1995) for example find that the demand for high-skilled workers is steadily rising, while low-skilled employment is subject to a considerable decline in many countries of the OECD. On the one hand, this might be explained by a growing supply of skills due to the educational expansion in the 1960s and 1970s. On the other hand, it can be argued, that the increasing international division of labour together with technological and organisational change have been leading to a unilateral rise in the demand for high-skilled labour whereas the low-skilled compete more and more with workers in low-wages countries (see Wood 1994; 2002). Furthermore, as a consequence of skill-biased technological and organisational changes more and more less qualified workers do not meet the increasing requirements of jobs on the domestic labour market (see Acemoglu 1998; 2002; Lindbeck and Snower 1996; Spitz-Oener 2006). Some authors also find evidence for a polarisation in skill-specific employment. Autor et al. (2003) hypothesise that highly standardised occupations of medium-skilled employees, such as book- and record-keeping, may be displaced more easily by technological innovations, e.g. by computer programmes, than comparatively simple and less standardised jobs, such as cleaning. Further empirical evidence for this hypothesis is provided by Manning (2004) or Goos and Manning (2007) for the UK and Spitz-Oener (2006) for Germany.

One aspect of the qualification specific changes on the labour market that has not received much attention up to now is the segregation by skill in the production process. The qualification-related structural change affects the internal skill structure of employment at the firm level. However, the changes in the skill composition within firms do not merely reflect the general shift to increasing shares of high-skilled workers in overall employment. Different theoretical models suggest that with proceeding economic integration and due to technological and organisational change segregation by education at the workplace is likely to increase (e.g. Kremer and Maskin 1996; Acemoglu 1999; Duranton 2004). In other words, more and more firms tend to employ predominantly one specific type of qualification. Some companies, such as fast-food or supermarket chains, recruit mainly low-skilled labour, while others tend to employ primarily high-skilled workers, as for instance software or high-tech producers. As a consequence, employees tend to work more often with similarly qualified co-workers and share less frequently a common workplace with differently skilled colleagues. Thus, production processes are characterised by an increasing segregation by skill.

According to these models a key determinant for the level of skill segregation is the level and the variety of skills in the labour force available to firms. Since production technologies and skill structures are characterised by pronounced regional disparities, there are likely significant differences in the level of segregation between regions. In particular, there might exist disparities between cities and rural areas. High-skilled workers are to be found more frequently in agglomerated areas because of their specific sector structure as well as urbanisation and localisation advantages. (for Germany see Fromhold-Eisebith and Schrattenecker 2006). Therefore, skill segregation could be more pronounced in agglomerated areas. Moreover, these models provide a link between the level of skill segregation and increasing wage inequalities between qualification groups. Potential effects on skill-specific productivity levels may translate into changes in skill specific employment prospects. Schlitte (2010) shows that skill segregation exerts an unfavourable effect on low-skilled employment in Western German regions. Thus, skill segregation in the production process is an important issue for regional labour market research and policy.

There are empirical studies that deal with the development of skill segregation at the national level pointing to an increasing separation of skill groups in several highly developed countries. Davis and Haltiwanger (1991) as well as Kremer and Maskin (1996) analyse the wage structure within and between firms in the U.S. manufacturing sector between 1975 and 1987. They find that the variance of wages between firms has increased more profoundly than wage disparities within firms. Based on these findings the authors conclude that the degree of skill segregation across workplaces has increased. Kramarz et al. (1996) provide evidence for increasing segregation by skill across firms in France. They show that it is more likely to find low-skilled employees at the same workplace in 1992 than in 1986. The same finding applies to high-skilled employees. Similar results for Germany are provided by Stephan (2001) analysing wage differentials within and across firms in Lower Saxony between 1994 and 2000, or by Gerlach et al. (2002) who investigate manufacturing firms between 1986 and 1992.

Overall, there is evidence for increasing levels of skill segregation in highly developed countries. However, there is a lack of studies investigating the phenomenon of skill segregation at the regional level. To the best of our knowledge this is the first analysis that considers regional disparities in segregation by skill. Furthermore, the paper aims at identifying characteristics of regional labour markets that influence the extent of skill segregation. In particular, we focus on the effect of high skilled labour supply on skill segregation at the workplace. Based on plant level information we use a direct measurement

of skill segregation. Our findings reveal that the skill segregation is marked by pronounced regional disparities in Germany. Moreover, the results show that the local endowment with human capital is an important determinant for the regional level of skill segregation. Although a rising stock of local human capital tends to have a positive effect on regional labour markets in general, the low-skilled might benefit to a lesser extent, because they tend to work in firms with relatively less modern and less complex production technologies decreasing their productivity and employment prospects.

The rest of the paper is organised as follows. In the next section we briefly outline theoretical explanations for increasing levels of skill segregation. Section 3 introduces the data set and Section 4 presents methodological issues on measuring skill segregation and the specification of our regression models. The results of our analysis are provided in Section 5. Finally, Section 6 concludes.

2 Theoretical Background

There are different theoretical approaches that link rising levels of skill segregation to proceeding economic integration and to technological and organisational change (e.g. Kremer and Maskin 1996; Acemoglu 1999; Duranton 2004). Although the mechanisms differ substantially, the models have in common that the skill structure of labour supply is a key determinant for skill segregation in the production process.

According to the model by Kremer and Maskin (1996) a firm is characterised by different tasks that are complementary on the one hand but also require different skills on the other hand. Hence, different skills within a firm are not perfectly substitutable. While the complementary relation of tasks promotes joint work processes involving workers from different skill groups, the asymmetry between the tasks favours segregated work processes. Whether the tasks within a firm are accomplished by a team consisting of similar or dissimilar qualification types depends on the degree of asymmetry in qualification requirements and on the heterogeneity in the structure of skills available to firms. An increasing level of skill segregation can be released by a rising dispersion of skills within the pool of labour available to firms and by increasing differences in the skill requirements that are needed to perform the tasks.

Acemoglu (1999) proposes a search theoretic model where human capital is assumed to be complementary to physical capital. As a consequence, firms try to adapt the production technology to the skills of the work force. Because of information asymmetries the firms are

not able to assess precisely the skills of potential employees beforehand. Investments in production technology, however, are made before staffing. Thus, the future internal skill structure can only be estimated by the company. This happens on the basis of the skill composition within the available pool of labour. When the supply of skills and the dispersion in the distribution of skills are relatively low, firms tend to create jobs that are suitable for a large range of skill types. While strong differences in skill levels make it easier for firms to distinguish high- from low-skilled workers, a large share of human capital raises the probability to employ a high-skilled person. Hence, in this model a rise in the supply of skills may be sufficient to release skill segregation. When the probability to hire a high-skilled person increases, more and more firms then tend to direct investments into technologies suitable to more skilled workers only. This leads to the exclusion of low-skilled workers from modern production technologies, in order to achieve higher productivity levels.

Duranton (2004) also assumes skills and technology to be complements. Each firm produces a good of a distinct quality and is either a supplier to other firms or a final good producer. Supply firms and the final good producer form a vertical production system. Because the quality of the intermediate goods has to comply with the quality of the final good, the quality level in a production system is determined by the final good producer. Furthermore, the quality of the produced good determines the complexity of the production technology and, therefore, the type of skill that is required for producing this good. Hence, aggregate production in an economy comprises vertical production systems that differ by the complexity of production process and the workers' skill level. There are two opposing forces working for or against segmentation into production systems. On the one hand, productivity gains by specialising on high-quality products are disproportionately high because of the complementary relation between physical and human capital. On the other hand, thick-market externalities that arise through a relatively large variety of intermediate goods supplied in large production systems work against segmentation. If the supply of high-skilled workers is comparatively high the relative importance of the thick-market externality declines and the incentives for firms to produce goods of a higher quality increase. Thus, with a rising share of human capital there is an increasing probability of production to be segmented into different vertical production systems that differ by the qualification levels of employees. In line with the model by Acemoglu (1999) a rising supply of high skills is sufficient to trigger skill segregation.

Closely related to the models described above, recent literature discusses more factors that may give rise to changes in the qualification structure and skill segregation. Gerlach et al.

(2002) and Tsertsvadze (2005) argue that an increasing fragmentation of production processes might influence the degree of segmentation by skill. According to this reasoning, proceeding economic integration caused by a decline of transport and communication costs boosts the use of intermediate products. Hence firms outsource parts of the production process and apply specialised intermediate products (see Autor 2001). They focus thereby on the work procedures for which they possess a comparative advantage. This development results in a specialisation of the staff on certain skill types. Findings in Tsertsvadze (2005) that base on German establishment data indicate that outsourcing significantly increases the probability for a firm to develop a relatively segregated qualification structure.

In line with the models presented above, Gerlach et al. (2002) argue that characteristics of the production technology probably influence segregation at the workplace since complementarities between technology and specific qualification levels might give rise to a decline of skill diversity within firms. Since production technologies likely differ between industries and different firm sizes, region-specific sector and firm-size structures probably form a source of regional disparities in skill segregation.

Overall, the increasing level of skill segregation in highly developed countries might be explained by changes in production conditions and in the skill composition of labour supply. A rise in the dispersion of skills as well as an increasing supply of high skills may release rising levels of skill segregation. Thus, the educational expansion in the 1960s and the 1970s might have generally increased the incentives for firms to apply more complex production technologies. Technological progress in turn might have raised the demand for high skills even further leading to the exclusion of less skilled workers from carrying out more complex tasks (see Griliches 1969; Lindbeck and Snower 1996). The models presented in this section provide mechanisms that link the skill structure of labour supply and changes in production conditions to skill segregation at the firm level. Hence, in our empirical analysis we focus on the role of human capital endowment as a potential determinant of regional disparities in skill segregation.

3 Data

We use functional regions as observational units (so-called Raumordnungsregionen) which consist of several counties (NUTS 3 regions) that are linked by intense commuting and should therefore serve as an approximation of regional labour markets. By applying functional regions most relevant processes such as job search, matching of vacancies and workers or the

adjustment of firm technology to skill specific labour supply, should take place within the regions. Altogether there are 97 functional regions in Germany that we consider in the descriptive analyses. However, we have to restrict the regression analysis to the 74 West German regions since the development of skill segregation in East Germany seems to be severely affected by the transformation process of the economy in the 1990s. Moreover, East and West Germany are still marked by systematic differences in the skill structure of the work force. These disparities seem to represent, at least partly, some kind of heritage of the educational systems of the two former German states. Furthermore, the analysis takes into account the region type. Starting from a classification based on a typology of settlement structure according to the criteria population density and size of the regional centre, we differentiate between agglomerated, urbanized and rural regions.[1]

In the literature different measures of segregation by skill are applied. Frequently the between- and within-plant wage dispersion serves as an indicator for segregation (e.g. Davis and Haltiwanger 1991, Kremer and Maskin 1996). However, we prefer a more direct measurement of skill segregation via the formal qualification of workers. Thus, we need plant level information on employment by educational attainment. The Establishment History Panel of the Institute for Employment Research (IAB) offers corresponding annual data. The dataset contains detailed information on all establishments in Germany with at least one employee liable to social security for East and West Germany for the period 1993 to 2005.[2] The data include a region identifier that allows aggregation of the establishment information to the regional level. The indicators of skill segregation are based on employment data differentiated by educational attainment of the workers. We can differentiate between 3 levels of education: no formal vocational qualification, completed apprenticeship and university degree that are subsequently denoted un- or low-skilled, medium-skilled and high-skilled, respectively. In order to control for effects arising from the rapidly growing number of marginal part-time workers we include only full-time employees in our analysis. Furthermore, all employees that have not been assigned to an educational level were excluded from our dataset.

In the regression analysis, we include several explanatory variables that rest on information from the employment statistics of the German Federal Employment Agency for the period 1993 to 2005. The employment statistic covers all employment subject to social security

[1] The classification has been developed by the Federal Office for Building and Regional Planning. For details see URL: http://www.bbr.bund.de/raumordnung/europa/download/spesp_indicator_description_may2000.pdf.

[2] For a detailed description of the Establishment History Panel see: http://fdz.iab.de/en/FDZ_Establishment_Data/Establishment_History_Panel.aspx.

contributions. The data is given on the NUTS 3 level and refers to workplace location. We use employment data differentiated by educational level, branch[3], occupation, and firm size in order to generate several explanatory variables.

4 Methodological issues

4.1 Measurement of skill segregation

In order to investigate regional disparities in skill segregation we use a segregation measure that assesses the extent of segregation between two distinct skill groups, i.e. workplace segregation of skilled- and unskilled workers. We use the Duncan index, also called index of dissimilarity, introduced by Duncan and Duncan (1955), which is one of the most frequently applied measures for group-specific segregation:

$$S_i = 0.5 * \sum_w \left| \frac{N_{wi}^u}{N_i^u} - \frac{N_{wi}^s}{N_i^s} \right|, 0 \le S_r \le 1 \qquad (1)$$

where N_{wi}^u (N_{wi}^s) denotes the number of unskilled (skilled) employees in workplace *w* and region *i*. The segregation measure S_i gives the proportion of low-skilled employees that has to be redistributed to other workplaces in order to get identical shares of high- and low-skilled employees at each workplace *w* in region *i*. In case of "no segregation" the Duncan index is equal to zero. In contrast, complete segregation is indicated by a value of one.

Economic and sociological literature provides a number of alternative measures of group-specific segregation that possess different properties.[4] In contrast to the Duncan index, some of these measures are sensitive to changes in the overall group shares. This applies for example to the co-worker index introduced by Hellerstein and Neumark (2003) or the OECD measure applied by Gerlach et al. (2002). As regards skill segregation these measures are thus affected by shifts in the regional skill shares even if the skill distribution across firms remains constant. It can be argued that changes in the relative group sizes matter for the degree of segregation irrespective of the distribution across firms. For instance, it might be reasonable to argue, that a doubling in the number of high-skilled employees in the labour force keeping

[3] Due to changes in the statistical recording of firms' affiliations to sectors, the information on the sector structure had to be back-dated from 1998 to earlier years. As a consequence, the data on the regional sector structure in the year prior to 1998 is only an approximation. Changes in the regional sector composition during that period might be underestimated.

[4] For a more extensive discussion about the properties of different segregation measures see for example Flückiger and Silber (1999) or Cutler et al. (1999).

constant the number of low-skilled employees increases segregation level of unskilled employees.

However, this analysis focuses on the determinants that make some firms hire predominantly skilled workers, while the others specialise on unskilled workers. According to the theoretical results discussed in Section 2 we hypothesise that the regional skill structure is a key factor regarding the incentive of firms to invest in skill-specific technologies and employ either skilled or unskilled workers. Since we include cross-sectional as well as longitudinal data in our analysis the segregation measure should be insensitive to changes in the regional skill composition. Therefore, scale invariance with respect to skill shares is a useful property for our purpose. Another useful characteristic of the Duncan index is that it is weighted by firm size. This ensures, that comparatively large firms matter more for the regional level of skill segregation than small firms.

In the following we use two different notions for the term "skilled worker" in our segregation measure. The first one includes only the high-skilled (= with university degree) and the second one includes all employees that have received a professional degree (= medium- and high-skilled). Hence, the following two variants of the Duncan index are applied in this study:

- Variant 1: Segregation between unskilled and high-skilled employees
- Variant 2: Segregation between unskilled and the rest of all other employees

The first variant is applied in order to find out whether skill segregation takes place between the bottom and the top end of the skill distribution, i.e. when the discrepancy between educational levels is relatively high. However, in Germany, where university degree generally correspond to a master's rather than to a bachelor's level the high-skilled represent a slightly more specific type of human capital than, for example, college degrees in the United States.[5] Hence, the relevance of joint work processes including academics and unskilled workers on the German labour market may be rather limited. Besides, the so-called dual education system, which combines formal schooling and on-the-job training produces a large number of highly skilled employees without university degree. In general, comprising a wide range of skills the group of workers with completed apprenticeship training is very heterogeneous. Overall, the cooperation between academics and unskilled workers might occur less frequent in production processes than to joint work of unskilled and medium-skilled employees, as for

[5] Bachelor and master degrees have been introduced only very recently to German universities and are not an issue for the time period observed in this paper.

example an unskilled and a supervising craftsman or a technician. Therefore, the second variant of our segregation measure aims at investigating whether skill segregation is characterised by a decoupling of unskilled workers from all other workers in the production process.

4.2 Regression analysis

The basic specification of the regression model that is applied to investigate the determinants of regional disparities in skill segregation links our pivotal explanatory variable, i.e. our proxy for human capital endowment, to the regional level of skill segregation:

$$S_{it} = \alpha_0 + \alpha_1 HC_{it-T} + \sum_{k=1}^{K} \beta_k C_{kit} + u_{it} \qquad (2)$$

where S_{it} is skill segregation in region i and year t. $HC_{it\text{-}T}$ is the lagged share of high skilled workers (university degree) in total employment and u_{it} is the error term. Since we assume that the impact of the local skill structure on skill segregation might not be immediate, but rather works via investments in technology and sets in somewhat deferred, the share of high-skilled workers enters into the model with a time lag.

Furthermore, we expand the basic specification by some control variables C_{kit} in order to avoid misspecification due to omitted variables. Controls comprise indicators for the sectoral specialisation of regional economies and the firm size structure of employment. We include the percentages of small (up to 49 employees) and large (250 or more employees) firms in total employment and the location coefficients of 20 branches.

There are some econometric issues in analysing the effect of high skilled labour supply on segregation by education. The first one is the omitted variable bias that can result from the potential correlation between unobserved regional characteristics and the dependent variable, i.e. the regional level of within plant skill segregation. We can deal with time-invariant regional characteristics by applying a fixed effects model:

$$S_{it} = \alpha_0 + \alpha_1 HC_{it-T} + \sum_{k=1}^{K} \beta_k C_{kit} + \eta_i + \lambda_t + \varepsilon_{it} \qquad (3)$$

where η_i denotes a region-specific effect, controlling for unobservable regional characteristics that are time-invariant, λ_t captures unobservable time effects and ε_{it} is a white noise error term. The region-specific effect will also capture any systematic differences in skill segregation between rural and urban regions.

The second econometric issue concerns the simultaneity bias resulting from reverse causality between regional human capital and skill segregation. Due to potential endogeneity of the employment share of high skilled labour the relationships estimated by OLS or a fixed effects model might not be interpreted as causal. According to the theoretical models outlined in Section 2, the differentiation of the regional economy into several production systems and the accompanying skill segregation likely give rise to significant differences in skill specific labour demand. Thus, we cannot assume that the regional human capital endowment is an exogenous variable. The simultaneity bias can be addressed using instrumental variable (IV) estimation. In order to identify the causal impact of high skilled labour supply on the dependent variable, we instrument the human capital variable by time lags of the share of high skilled workers applying two-stage-least-squares (2SLS) estimation. The lags are valid instruments if they are relevant and uncorrelated with the error term. More precisely, relevance requires a partial correlation of the instrument with the endogenous regressor, namely, the coefficient of the instrument variable should be significant in the first stage regression.

Finally, we might consider spillover effects among neighbouring labour markets. Spatial interaction should mainly take place within our observational units because we apply functional regions. However, we cannot preclude significant spillover effects across the borders of regional labour markets. Spatial dependence might be an issue although the models in Section 2 provide no theoretical arguments for important interaction among neighbouring regions as regards disparities in skill segregation. The models imply that the supply of high skilled labour affects the firm's choice of production technology and this in turn might give rise to segregation by skill. Firms may also take into account labour supply in nearby regions when deciding on investments in technology as neighbouring labour markets are likely linked by the mobility of workers, i.e. migration and commuting. We introduce a spatial lag of human capital in the regression model to account for these effects:

$$S_{it} = \alpha_0 + \alpha_1 HC_{it-T} + \rho \sum_{j=1}^{R} \omega_{ij} HC_{jt-T} + \sum_{k=1}^{K} \beta_k C_{kit} + \eta_i + \lambda_t + \varepsilon_{it} \qquad (4)$$

Thus we extend the non-spatial model by a spatial lag of the pivotal explanatory variable $\sum_{j=1}^{R} \omega_{ij} HC_{jt-T}$ where ω_{ij} is an element of the $R \times R$ spatial weights matrix Ω.[6]

[6] In order to check the robustness of results with respect to variation of the spatial weighting scheme we apply two different weighting schemes. The first specification of Ω is a binary spatial weights matrix such that $\omega_{ij} = 1$

Taking into account the weighted sum of human capital in neighbouring regions implies that spatial autocorrelation of the error term is caused by omission of some substantive form of spatial dependence caused by neighbourhood effects. However, spatial autocorrelation in measurement errors or in variables that are otherwise not crucial to the model might also entail spatial error dependence. Provided that the unobservable common factors are uncorrelated with the explanatory variables, the coefficient estimates from the non-spatial model are still unbiased, but standard error estimates are biased and hence statistical inference that is based on such standard errors is invalid. To deal with this issue we apply the nonparametric covariance matrix estimator introduced by Driscoll and Kraay (1998), which provides heteroscedasticity consistent standard errors that are robust to very general forms of spatial and temporal dependence.[7]

5 Evidence on regional disparities in skill segregation among German regions

5.1 Descriptive overview

This section illustrates the development and level of segregation by skill in the period 1993 to 2005. In addition to the distinction between East and West Germany we provide evidence on skill segregation for 97 functional regions and for three different area types.

Skill segregation in Germany is marked by a distinctive increase in the overall level between 1993 and 2005 (see Table 1). This increase in the level of skill segregation, however, has been particularly strong during the 1990s. Since 1999, by contrast, we observe only small changes in segregation levels. Overall, this result is in line with previous findings that point to an increase of segregation by skill in developed economies. Hence, according to both variants of skill segregation differently skilled workers tend to work more and more in different firms rather than sharing a common workplace. Unsurprisingly, the level of skill segregation between unskilled and high-skilled workers (Variant 1) is higher than in the case of Variant 2 (between unskilled and all other workers).

[Table 1 around here]

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if the largest municipalities of regions *i* and *j* are within reach of not more than 100 km to each other and $\omega_{ij} = 0$ otherwise. Secondly, ω_{ij} is set to the inverse of distance between the largest municipalities of regions *i* and *j*.

[7] See Hoechle (2007) for more details.

Most noticeable, the development as well as the level of skill-segregation is marked by a pronounced east-west gradient. Both variants of segregation measurement display a substantially higher level in East Germany (Table 1). The development of skill segregation in East German regions in the period under consideration is likely driven by the impact of economic transformation. Moreover, systematic differences in the development of the skill composition in East and West Germany in the 1990s might have affected the changes in skill segregation. For instance, findings by Fromhold-Eisebith and Schrattenecker (2006) show that the share of high-skilled employment declined dramatically while the share of low-skilled employment increased in most East German regions. This is in strong contrast to the development of the skill composition in West Germany.

[Figures 1 and 2 around here]

Figure 1 and Figure 2 reveal changes in the spatial pattern of skill segregation. Overall, skill segregation has been increasing in most German regions between 1993 and 2005. Only ten regions in Variant 1 and two regions in Variant 2 out of 97 regions experienced declining levels of segregation. As shown in Table 1 the increase of segregation in East German regions is much stronger than in West Germany. According to the correlation coefficient shown in Table 1 regions with relatively low initial levels of skill segregation in 1993 have subsequently exhibited on average a more pronounced increase of skill segregation than those with comparatively high initial levels. This applies to the entire cross section as well as to the East and West German subsamples.

Figure 3 and 4 indicate that despite this convergence since 1993 there are still substantial disparities in skill segregation across German regions in 2005. With exception of Ingolstadt (in the south of West Germany), the most highly segregated regions are situated exclusively in East Germany. Segregation levels do not only differ between East and West, but there is also a significant variation of regional segregation levels within East and West Germany. However, because of the likely influence of transformation effects on the level of skill segregation in East Germany the following analyses on regional disparities in skill segregation are restricted to the West German subsample.

In Braunschweig for example 57 % of the low-skilled would have to be redistributed to other firms in order to get identical shares of high- and low-skilled employees at each firm in 2005. By contrast in Cloppenburg 84 % of low skilled workers would have to swap their workplace with higher skilled workers in other firms. While the least segregated regions are mainly located in the southern part of the country, the spatial pattern in the northern part appears to

be rather scattered. Along the eastern and southern boundaries of West Germany the degree of skill segregation tends to be comparatively low.

[Figures 3 and 4 around here]

We also investigate the development of skill segregation by different area types, i.e. agglomerated, urbanised and rural areas. Regarding the first variant (segregation between unskilled and high-skilled employees), agglomerated areas are characterised by a higher level of segregation by skill than urbanised and rural areas throughout the entire period (see Figure 5). Moreover, it is discernible that the differences between the three region types have been somewhat increasing since the end of the 1990s. While skill segregation in rural areas has remained on a more or less constant level, skill segregation in urbanised and agglomerated areas have been increasing. As illustrated in Figure 6, levels of skill segregation across area types in Variant 2 (segregation between unskilled and all other workers) are very similar during the 1990s but start to diverge at the end of the decade.

[Figures 5 and 6 around here]

5.2 Regression results

As shown in the previous section transformation effects seem to severely influence the level of skill segregation in Eastern Germany during our period of observation. Since these effects are likely to interfere, we exclude the East German regions from the regression analysis. The estimation results are presented in Tables 2 and 3. The models displayed in the tables only differ with respect to the applied measure of skill segregation (Variants 1 and 2). They provide results for the equations (3) and (4), i.e. with and without considering a spatial lag of human capital in the regression model, both including our proxy for the skill share in labour supply as well as employment shares of small and large firms and various branches. In addition to standard fixed effects estimations, the tables present the estimates obtained by applying Driscoll and Kraay standard errors and IV estimation.

In the standard fixed effects model the human capital measure enters without time lag. However, we also consider specifications where skill shares enter with different time lags. The results indicate that the impact of high skilled labour supply is not immediate. Irrespective of the variant of skill segregation measurement, the unlagged share of high-skilled workers yields a positive but insignificant coefficient. However, in both cases the corresponding coefficients are statistically significant with a lag of two periods (at the 5 %

level in Variant 1 and at the 1 % level in Variant 2).[8] Hence, the findings suggest that the regional level of skill segregation is significantly and positively affected by previous shares of local human capital. This might reflect that investments in skill-specific technologies and its impact on skill segregation due to changes in the supply of human capital emerge only decelerated in time. According to our results a relatively large share of employees that received a tertiary education positively affects segregation between low- and high-skilled employees at the firm level (Variant 1) as well as segregation between the low-skilled and the rest of all employees (Variant 2) within about two years time.

[Tables 2 and 3 around here]

The results of the 2SLS estimations suggest that endogeneity of the regional human capital endowment is unlikely to be a major problem. We apply the share of high skilled workers lagged by six years as an instrument for human capital. According to the first-stage regressions the share of high-skilled lagged by six periods is a valid instrument. The high significance (at the 0.01-level) of the instrument in the first stage regression indicates that the partial correlation between the instrument and the endogenous explanatory variable is sufficient to ensure unbiased estimates and relatively small standard errors.[9] The impact of regional human capital endowment on skill segregation is even reinforced in the IV regressions. According to IV estimation results an increase in the share of local high-skilled employment by one percentage point increases the level of segregation, i.e. the share of unskilled employees that has to be redistributed in order to maintain no skill segregation, by 0.56 percentage points in Variant 1 and 0.62 percentage points in Variant 2.

The IV estimates are positive, significant, and larger than their simple fixed effects counterparts for both variants of segregation measurement. This is surprising since simultaneity should result in upward biased fixed-effects estimates of the impact of human capital. This suggests that the simultaneity bias in the fixed effects estimates is relatively small. The gap between fixed effects and IV estimates might reflect a downward bias in the fixed effects estimates caused by measurement errors. This may indicate that the measurement error's bias towards zero is more important than the upward bias due to the impact of segregation on the regional human capital. Another explanation is that there is heterogeneity

[8] The estimation results including skill shares with different time lags can be obtained from the authors upon request.

[9] The first-stage estimation results can be obtained from the authors upon request.

in the effect of high skilled labour supply on skill segregation, and that the IV estimates tend to recover effects for a subset of regions with relatively strong impact of human capital on segregation.[10]

Including the spatially lagged share of high-skilled employment (Equation 4) does not ultimately change these findings. For instance, applying a binary spatial weights matrix as specified above does only slightly affect the sizes as well as the significances of the estimates for the local skill supply (see Tables 2 and 3). In both segregation variants the corresponding coefficients in the spatial models are somewhat below those in the non-spatial model. The marginal effect in the spatial IV model for example reduces from 0.56 to 0.51 in Variant 1 and from 0.62 to 0.55 in Variant 2. Thus, ignoring spatial dependence yields a small upwards bias in the estimates for the local skill supply. Nevertheless, this does not alter our conclusions in general. The coefficients of the spatially lagged variable are significantly positive for each model specification reported in the tables. However, while the estimates for local skill supply are robust to changes in the specification of the spatial weight matrix the coefficients of the spatially lagged skill shares are sensitive to alternative weighting schemes.[11] Increasing the distance cut-off, that is expanding the area of surrounding regions considered for spatial interaction, to 150 and more kilometres affects the coefficients' size and significance. Overall, this indicates that firms take into account labour supply in nearby regions, i.e. within reach of 100 kilometres, when deciding on investments in technology.

Furthermore, our results do not alter by applying Driscoll and Kraay (1998) standard errors that are robust to heteroscedasticity and general forms of cross-sectional and time series autocorrelation. Tables 2 and 3 show the fixed-effects estimates (Equation 3) with robust standard errors including the share of human capital lagged by two periods. Thus, we can preclude spatial autocorrelation in measurement errors, such as a wrongly specified regional system to seriously affect statistical inference.

The coefficients of the control variables show that both the firm-size structure and specialisation of the regional economy on specific branches matter for the level of segregation by skill. The coefficients of the employment shares of small and of large firms are significantly negative in the case of Variant 1. Thus, the phenomenon of segregation between unskilled workers and university graduates seems to be more pronounced in regional labour

[10] See Card (2001) for a corresponding reasoning with respect to returns to schooling.

[11] The results applying alternative weighting schemes can be obtained upon request by the authors.

markets characterised by large share of medium sized firms. The second variant of skill segregation is only significantly and negatively affected by the percentage of small firms.

In both variants the results for the location coefficients of specific branches show that a specialisation in manufacturing branches tends to correlate negatively with segregation by skill. The only exceptions are the branches “Food, Drink and Tobacco” and “Textiles and Leather”. In particular, regarding Variant 2 most of the estimated effects significantly differ from zero. By contrast, in the service sector the majority of the coefficients exhibit positive signs. However, the branches “Finance and Insurance” and “Simple Business-related Services” also exert a negative influence on skill segregation. Altogether, these findings suggest that sectoral specialisation has differentiated effects on skill segregation. Whereas some branches tend to boost segregation by skill, other industries, mainly manufacturing branches, seem to dampen the regional intensity of segregation. Moreover, the sector structure seems to be slightly more important for segregation between the unskilled and the rest of all workers.

Overall our empirical models explain a significant part of the regional disparities in skill segregation. According to the R^2 of the within estimators nearly 40% in Variant 1 and around 60% in Variant 2 of the (within) variation can be explained by our model. Moreover, the results show that the regional supply of skilled labour is indeed a key determinant as regards the development of within-firm segregation by skill, which is in line with the theoretical models presented in Section 2.

6 Conclusions

Our analysis aims at investigating regional disparities in workplace segregation by skill and its determinants. While previous analyses examine skill segregation mainly on the national level, we provide first evidence on regional disparities in segregation by skills. Applying the Duncan index on regional and firm-level data we investigate two variants of skill segregation at the regional level, namely segregation between unskilled and high-skilled workers and segregation between unskilled and the rest of all workers. The results point to pronounced regional disparities in the level of skill segregation across German regions for both types of segregation. Furthermore, the development of skill segregation is marked by a distinctive increase between 1993 and 2005. Due to transformation process in the 1990s and systematic differences in the qualification structure between East and West Germany the development and levels of skill segregation differ substantially between both parts of the country. In

contrast, we detect only small disparities between urban and rural areas by the end of the 1990s. However, since 2000 the development of segregation across different area types seems to diverge. Especially in more densely populated areas the relatively strong increases in the level of skill segregation may negatively impact the employment prospects for the low-skilled.

The regression analysis reveals significant effects of the local skill composition on the level of skill segregation. Skill segregation is positively affected by a large local supply of human capital. We assume that the effect of the local skill structure works via investments in technology and sets in somewhat deferred. Applying different time lags demonstrates that the impact of the local skill supply on segregation levels is not immediate, but sets in with a delay of about two years. Furthermore, including a spatially lagged share of human capital in our regression model shows that firms also take the skill supply in nearby regions into account when making decisions on investments in production technology. This, however, does not ultimately affect the estimates on our proxy for the local supply of human capital.

Overall, our findings are in line with theoretical results providing a link between proceeding economic integration and technological change on the one hand and rising levels of skill segregation in the production process on the other hand. In the corresponding models the supply of human capital is a key determinant for the segmentation of skills in the production process. Thus, for Germany as a highly developed country we identify an important factor with respect to increasing skill segregation. Furthermore, our findings indicate that sectoral specialisation as well as the firm-size structure matter for the regional level of skill segregation. This possibly reflects different skill compositions across firm-size classes and branches. The latter can be explained by differences in production technologies.

The theoretical results discussed in Section 2 further propose a link between skill segregation and rising wage inequalities as well as the possibility of adverse effects on low-skilled employment. Schlitte (2010) provides evidence on adverse effects of segregation on labour market prospects of low-skilled. Thus, due to adverse effects from skill segregation the low-skilled might benefit less from the positive labour market effects of local human capital that are frequently found in the literature. Therefore, our findings on the determinants for the regional level of skill segregation have important implications for regional labour market policy.

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Appendix

Table 1. Segregation in East and West Germany

	East Germany		West Germany		Germany	
	Variant 1	Variant 2	Variant 1	Variant 2	Variant 1	Variant 2
1993						
Duncan index	0.727	0.603	0.718	0.534	0.738	0.564
1999						
Duncan index	0.784	0.69	0.739	0.567	0.755	0.599
2005						
Duncan index	0.795	0.694	0.747	0.574	0.761	0.602
1993-2005						
change of Duncan index	0.068	0.091	0.029	0.04	0.023	0.038
correlation: level in 1993 and change between 1993 and 2005	-0.658	-0.335	-0.524	-0.283	-0.379	0.274
R^2	0.433	0.112	0.274	0.08	0.144	0.075

Table 2. Estimation results (Variant 1)

Model	FE		FE-Robust		IV	
Skill supply (lagged by 2 years)	0.404 **	0.378 **	0.404 *	0.378 *	0.558 ***	0.508 ***
	(0.159)	(0.158)	(0.207)	(0.191)	(0.185)	(0.183)
Spatially lagged skill supply	-	1.013 ***	-	1.013 ***	-	0.790 **
	-	(0.346)	-	(0.141)	-	(0.396)
Small firms	-0.477 ***	-0.460 ***	-0.477 ***	-0.460 ***	-0.461 ***	-0.451 ***
	(0.104)	(0.103)	(0.147)	(0.148)	(0.104)	(0.104)
Largs firms	-0.218 ***	-0.212 ***	-0.218 *	-0.212 *	-0.209 ***	-0.207 ***
	(0.071)	(0.071)	(0.125)	(0.121)	(0.071)	(0.071)
Food, Drink & Tobacco	0.020 **	0.019 **	0.020 ***	0.019 ***	0.021 **	0.020 **
	(0.008)	(0.008)	(0.006)	(0.006)	(0.008)	(0.008)
Textile & Leather	0.006 *	0.007 **	0.006	0.007 *	0.006 *	0.007 **
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Wood	0.000	-0.002	0.000	-0.002	0.001	-0.001
	(0.004)	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)
Paper & Printing	-0.014	-0.012	-0.014	-0.012	-0.012	-0.011
	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.010)
Chemistry and Synthetic Materials	-0.007	-0.005	-0.007 *	-0.005	-0.006	-0.005
	(0.006)	(0.006)	(0.004)	(0.004)	(0.006)	(0.006)
Glass & Ceramics	-0.001	0.000	-0.001	0.000	-0.001	-0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Metal-Production & Manufactoring	-0.005	-0.004	-0.005	-0.004	-0.004	-0.003
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Machinery	-0.015 **	-0.016 **	-0.015 ***	-0.016 ***	-0.014 **	-0.015 **
	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)
Electrical Engineering	-0.001	0.001	-0.001	0.001	0.000	0.001
	(0.007)	(0.007)	(0.006)	(0.006)	(0.007)	(0.007)
Motor Vehicles	-0.007 *	-0.007 *	-0.007	-0.007	-0.007 *	-0.007 *
	(0.004)	(0.004)	(0.011)	(0.011)	(0.004)	(0.004)
Building & Construction	0.000	-0.001	0.000	-0.001	0.004	0.002
	(0.013)	(0.013)	(0.009)	(0.009)	(0.013)	(0.013)
Commerce	-0.019	-0.028	-0.019	-0.028	-0.018	-0.026
	(0.024)	(0.025)	(0.019)	(0.019)	(0.024)	(0.025)
Hotels & Gastronomy	0.042 ***	0.045 ***	0.042 ***	0.045 ***	0.041 ***	0.044 ***
	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.010)
Information & Transportation	0.020 **	0.017 *	0.020 **	0.017 **	0.022 **	0.019 *
	(0.010)	(0.010)	(0.008)	(0.008)	(0.010)	(0.010)
Finance & Insurance	-0.046 ***	-0.041 **	-0.046	-0.041	-0.047 ***	-0.043 **
	(0.017)	(0.017)	(0.031)	(0.030)	(0.017)	(0.017)
Simple Business-Related Services	-0.011	-0.014	-0.011 **	-0.014 ***	-0.010	-0.012
	(0.009)	(0.009)	(0.005)	(0.005)	(0.009)	(0.009)
Complex Business-Related Services	0.020 **	0.017 *	0.020 *	0.017	0.018 *	0.016
	(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.010)
Temporary Employment	0.004	0.003	0.004	0.003	0.005	0.004
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
Education	0.006	0.007	0.006	0.007 *	0.006	0.007
	(0.006)	(0.006)	(0.004)	(0.004)	(0.006)	(0.006)
Health & Social Services	0.037 **	0.034 **	0.037 ***	0.034 **	0.038 **	0.035 **
	(0.017)	(0.017)	(0.014)	(0.013)	(0.017)	(0.017)
Constant	0.940 ***	0.855 ***	0.940 ***	0.855 ***	0.906 ***	0.846 ***
	(0.077)	(0.082)	(0.090)	(0.099)	(0.080)	(0.087)
R2 within	0.382	0.388	0.382	0.388	0.381	0.388
R2 between	0.090	0.053	-	-	0.078	0.054
R2 overall	0.125	0.087	-	-	0.113	0.089
No. of obs.	962	962	962	962	962	962

Notes: *** significant at the 0.01-level; ** significant at the 0.05-level, * significant at the 0.1-level. Standard errors reported in parentheses.

Table 3. Estimation results (Variant 2)

Model	FE		FE-Robust		IV	
Skill supply (lagged by 2 years)	0.325 ***	0.300 **	0.325 ***	0.300 ***	0.616 ***	0.546 ***
	(0.117)	(0.117)	(0.120)	(0.101)	(0.137)	(0.135)
Spatially lagged skill supply	-	0.976 ***	-	0.976 ***	-	1.097 ***
	-	(0.255)	-	(0.118)	-	(0.293)
Small firms	-0.209 ***	-0.193 **	-0.209 ***	-0.193 ***	-0.179 **	-0.165 **
	(0.077)	(0.076)	(0.072)	(0.071)	(0.077)	(0.077)
Largs firms	0.005	0.010	0.005	0.010	0.020	0.024
	(0.053)	(0.052)	(0.087)	(0.084)	(0.053)	(0.052)
Food, Drink & Tobacco	0.023 ***	0.022 ***	0.023 ***	0.022 ***	0.024 ***	0.022 ***
	(0.006)	(0.006)	(0.004)	(0.004)	(0.006)	(0.006)
Textile & Leather	0.007 ***	0.008 ***	0.007 *	0.008 *	0.007 ***	0.008 ***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Wood	-0.002	-0.004	-0.002 *	-0.004 ***	-0.002	-0.004
	(0.003)	(0.003)	(0.001)	(0.001)	(0.003)	(0.003)
Paper & Printing	-0.022 ***	-0.020 ***	-0.022 ***	-0.020 ***	-0.019 **	-0.017 **
	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.008)
Chemistry and Synthetic Materials	-0.009 *	-0.007	-0.009	-0.007	-0.008	-0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Glass & Ceramics	-0.003	-0.002	-0.003 *	-0.002	-0.003	-0.002
	(0.003)	(0.003)	(0.001)	(0.001)	(0.003)	(0.003)
Metal-Production & Manufactoring	-0.012 **	-0.010 *	-0.012 **	-0.010 *	-0.010 *	-0.008
	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.006)
Machinery	-0.001	-0.002	-0.001	-0.002	0.001	0.000
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
Electrical Engineering	-0.012 **	-0.010 **	-0.012 ***	-0.010 ***	-0.011 **	-0.009 *
	(0.005)	(0.005)	(0.003)	(0.003)	(0.005)	(0.005)
Motor Vehicles	-0.009 ***	-0.009 ***	-0.009	-0.009	-0.008 ***	-0.008 ***
	(0.003)	(0.003)	(0.011)	(0.012)	(0.003)	(0.003)
Building & Construction	0.002	0.000	0.002	0.000	0.009	0.006
	(0.010)	(0.010)	(0.008)	(0.007)	(0.010)	(0.010)
Commerce	-0.011	-0.020	-0.011	-0.020	-0.009	-0.019
	(0.018)	(0.018)	(0.015)	(0.015)	(0.018)	(0.018)
Hotels & Gastronomy	0.019 ***	0.022 ***	0.019 ***	0.022 ***	0.018 **	0.021 ***
	(0.008)	(0.007)	(0.006)	(0.006)	(0.008)	(0.008)
Information & Transportation	0.017 **	0.014 *	0.017 ***	0.014 **	0.020 ***	0.016 **
	(0.007)	(0.007)	(0.005)	(0.006)	(0.007)	(0.007)
Finance & Insurance	-0.029 **	-0.024 *	-0.029	-0.024	-0.031 **	-0.025 **
	(0.013)	(0.013)	(0.019)	(0.018)	(0.013)	(0.013)
Simple Business-Related Services	-0.014 **	-0.017 ***	-0.014 ***	-0.017 ***	-0.012 *	-0.015 **
	(0.007)	(0.006)	(0.004)	(0.004)	(0.007)	(0.007)
Complex Business-Related Services	0.031 ***	0.028 ***	0.031 **	0.028 **	0.027 ***	0.024 ***
	(0.007)	(0.007)	(0.012)	(0.012)	(0.008)	(0.008)
Temporary Employment	-0.001	-0.002	-0.001	-0.002	0.001	-0.001
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
Education	0.005	0.005	0.005	0.005	0.005	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Health & Social Services	0.017	0.014	0.017 **	0.014 *	0.019	0.015
	(0.013)	(0.013)	(0.008)	(0.008)	(0.013)	(0.013)
Constant	0.636 ***	0.554 ***	0.636 ***	0.554 ***	0.570 ***	0.487 ***
	(0.057)	(0.061)	(0.034)	(0.042)	(0.060)	(0.064)
R2 within	0.604	0.610	0.604	0.610	0.601	0.608
R2 between	0.055	0.046	-	-	0.034	0.028
R2 overall	0.118	0.110	-	-	0.089	0.084
No. of obs.	962	962	962	962	962	962

Notes: *** significant at the 0.01-level; ** significant at the 0.05-level, * significant at the 0.1-level. Standard errors reported in parentheses.

Figure 1. Changes in the regional level of skill segregation 1993 to 2005 (Variant 1), Duncan Index, percentage points

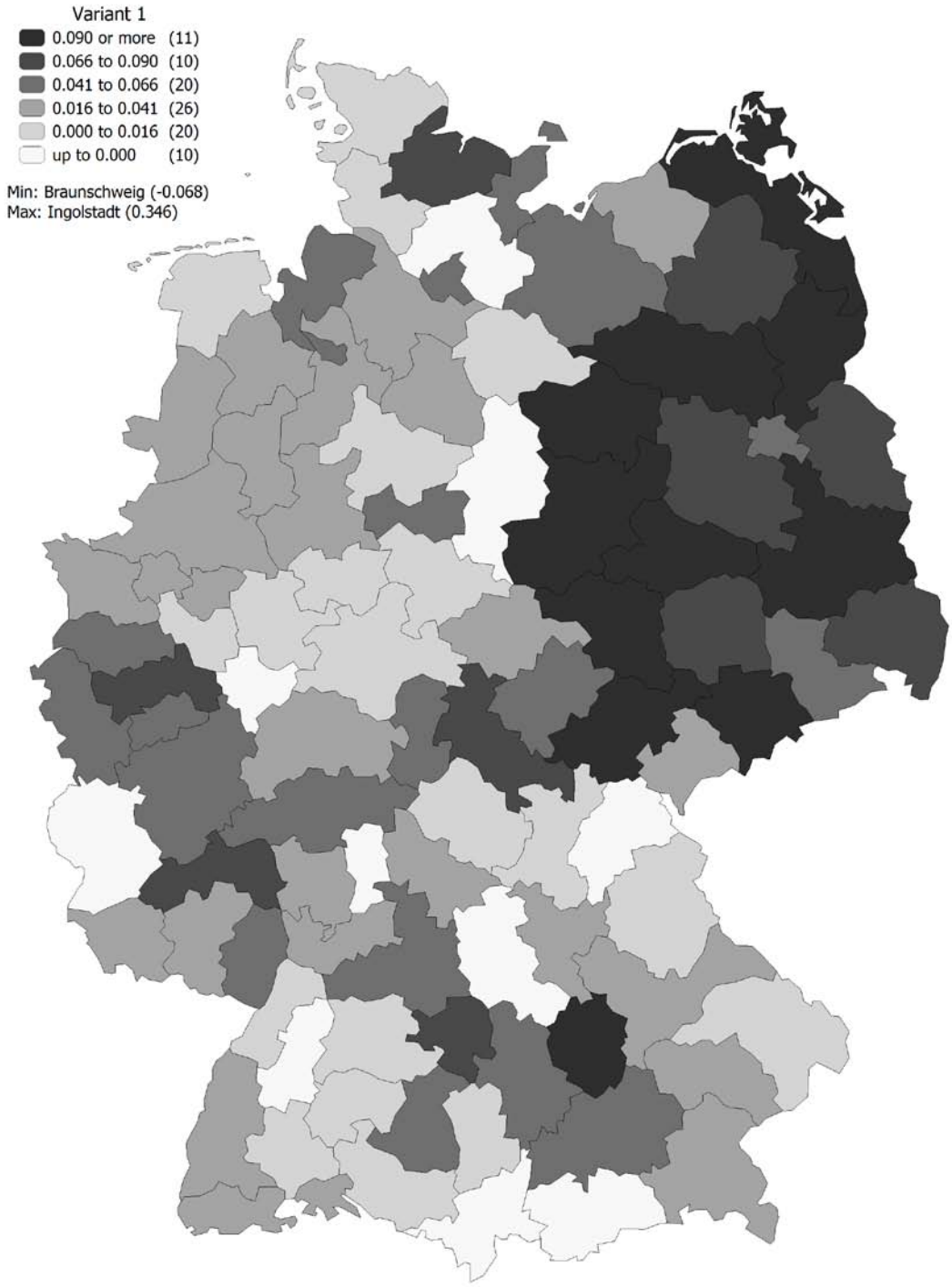


Figure 2. Changes in the regional level of skill segregation 1993 to 2005 (Variant 2), Duncan Index, percentage points

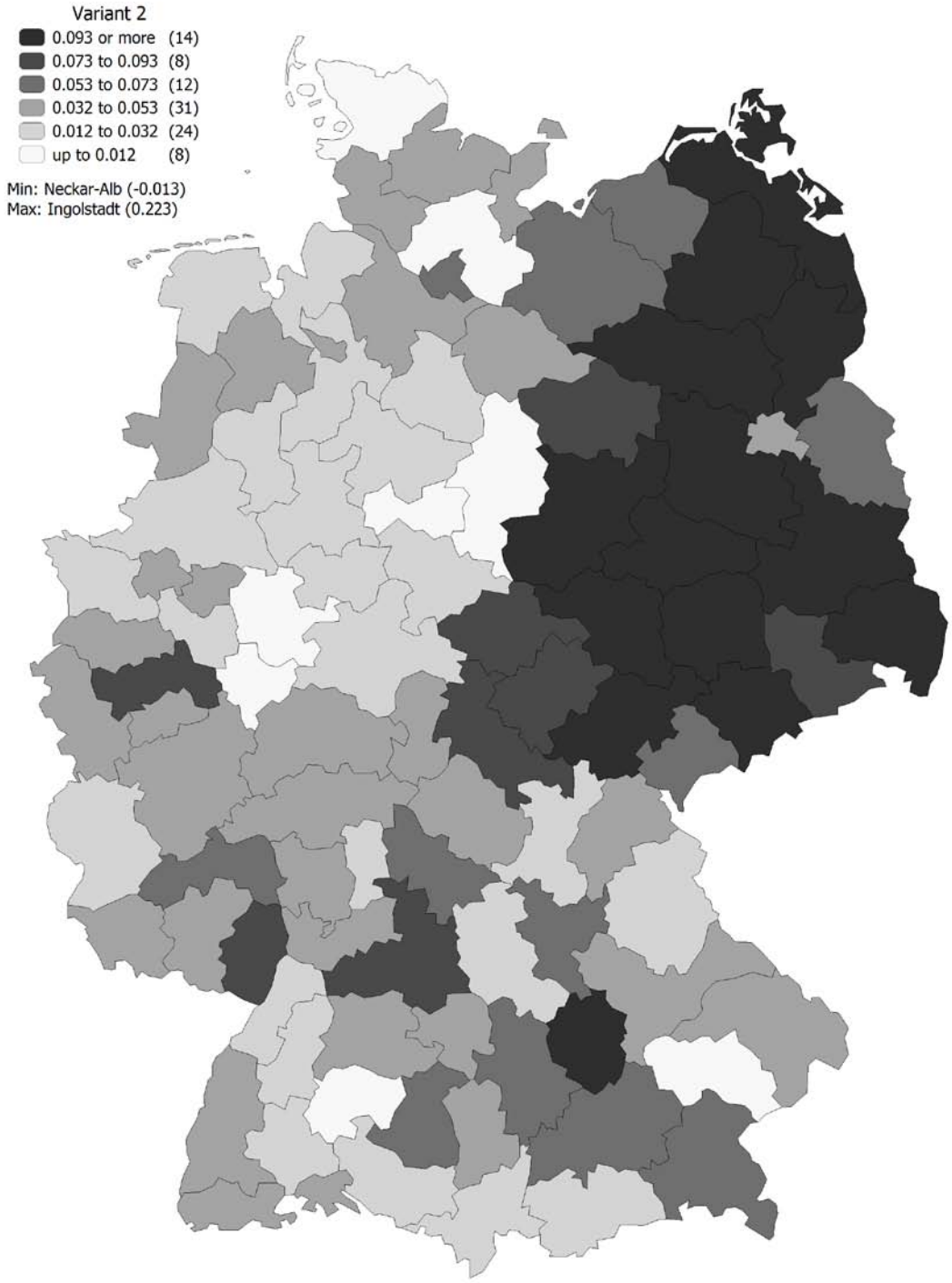


Figure 3. Regional levels of skill segregation 2005 (Variant 1), Duncan Index

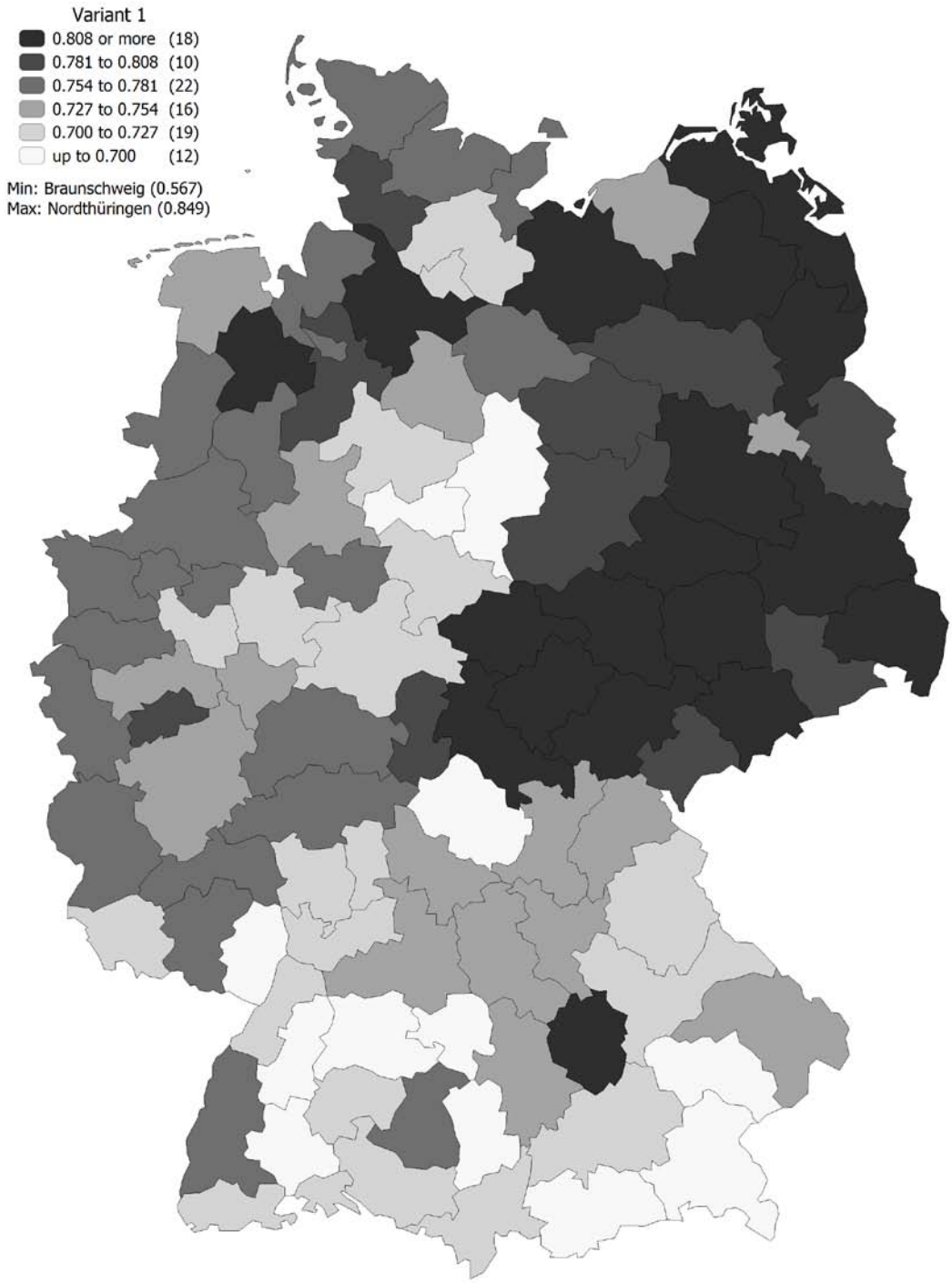


Figure 4 Regional levels of skill segregation 2005 (Variant 2), Duncan Index

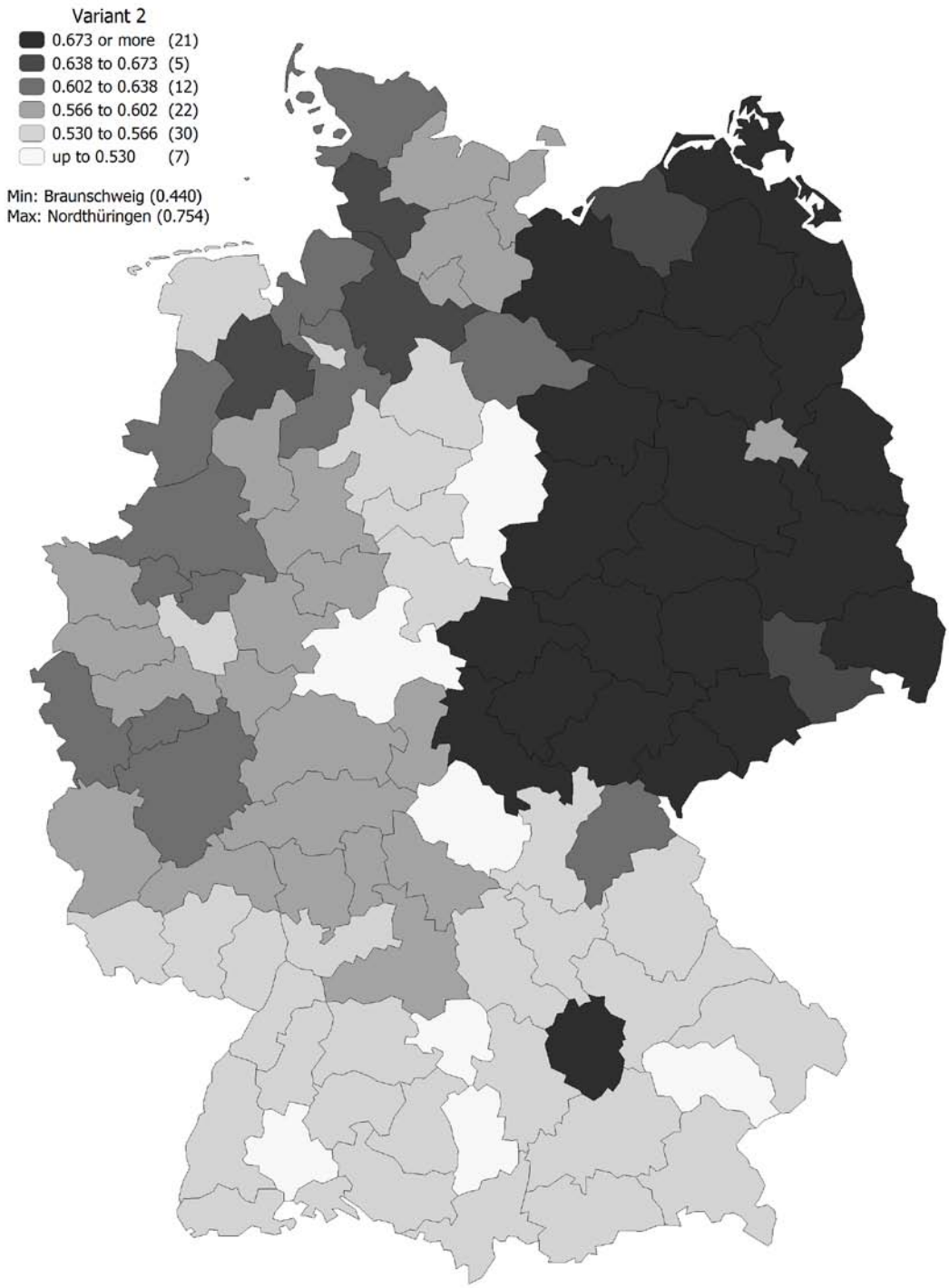


Figure 5. Skill segregation by area types in West Germany, 1993 to 2005 (Variant 1)

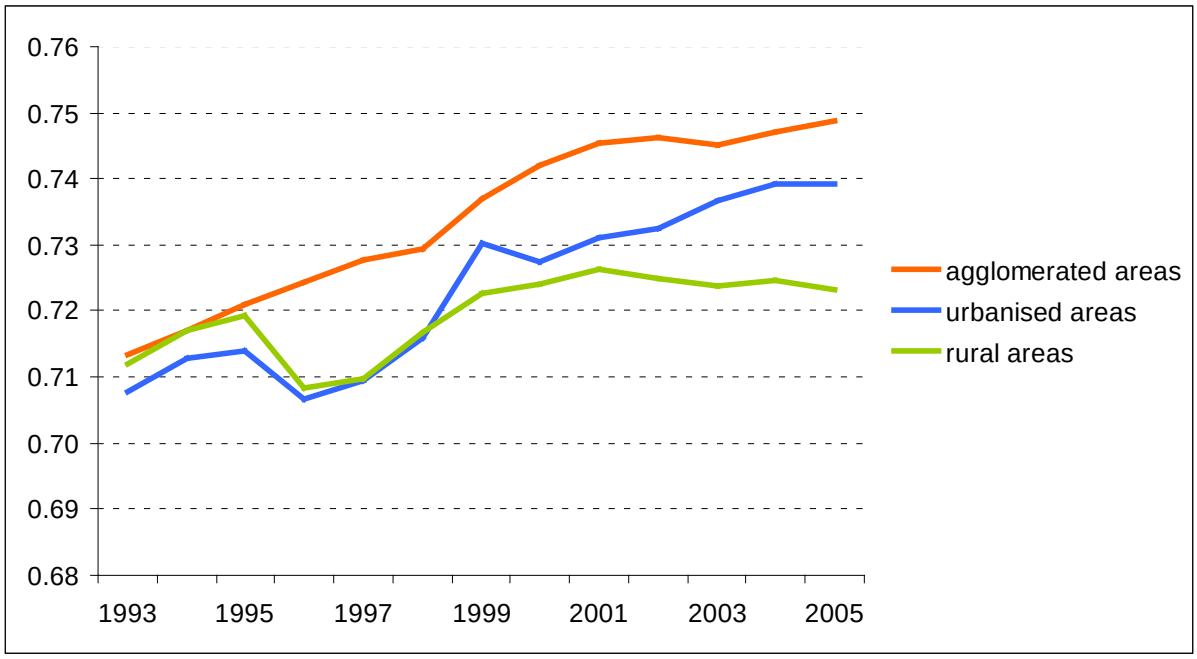
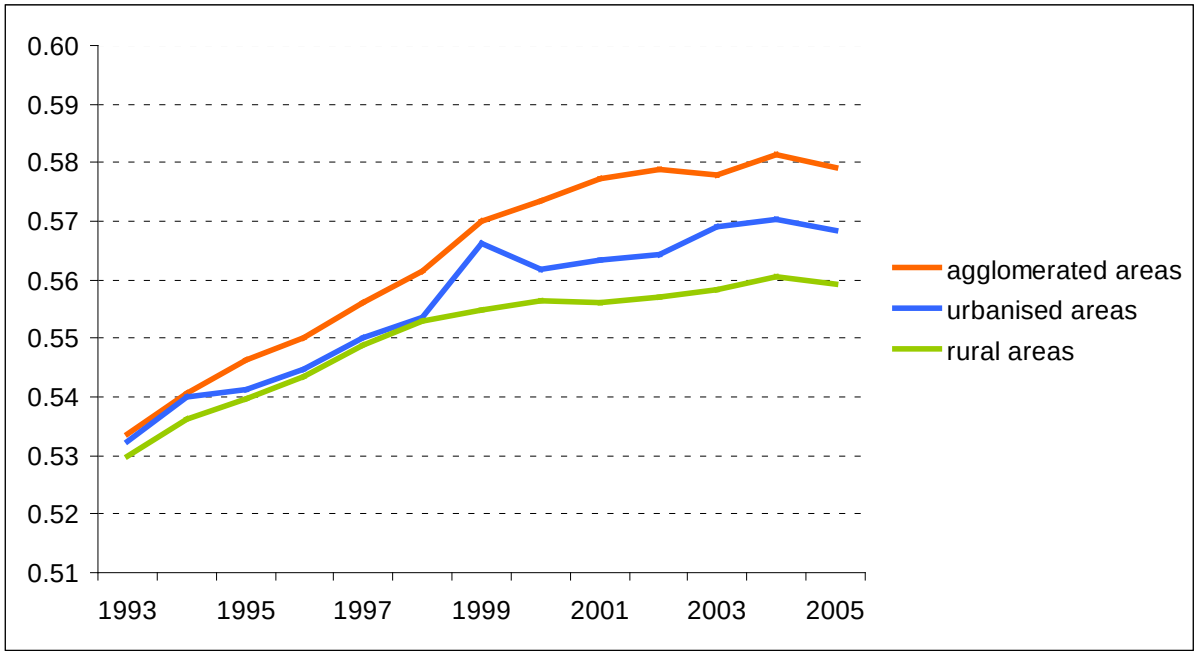


Figure 6. Skill segregation by area types West Germany, 1993 to 2005 (Variant 2)



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