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## Local human capital, segregation by skill, and skill-specific employment growth

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# Local human capital, segregation by skill, and skill-specific employment growth

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## Contents

Abstract .....	4
Zusammenfassung .....	4
1 Introduction .....	5
2 Literature.....	7
2.1 Human capital externalities and skill complementarities .....	7
2.2 Human capital, skill segregation and employment growth .....	8
3 Data .....	10
4 Skill segregation .....	11
4.1 Measuring skill segregation.....	11
4.2 Skill segregation in Western German regions .....	13
5 Regression model.....	17
5.1 Specification .....	17
5.2 Results .....	19
6 Conclusions .....	23
Literature .....	25

## Abstract

Labour markets in most highly developed countries are marked by rising levels of skill segregation in the production process and increasing inequalities in skill-specific employment prospects. Local human capital has a likely effect on skill specific productivity levels and employment growth. Furthermore, theoretical studies suggest that skill segregation might matter for the polarisation of wages and employment. There are several studies investigating the influence of the local human capital endowment on qualification-specific wages levels. However, analyses on regional employment growth by different skill levels are still scarce and empirical evidence on the effects of skill segregation on qualification-specific employment is completely lacking. This paper investigates the effects of the local skill composition and skill segregation in the production process on qualification-specific employment growth in West German regions. This study provides first evidence for negative effects of skill segregation on low-skilled employment growth. Furthermore, the results show that a large share of local high-skilled employment does not foster further regional concentration of human capital but positively affects the employment prospects of less skilled workers.

## Zusammenfassung

Die Arbeitsmärkte in den meisten hochentwickelten Staaten sind von einer zunehmenden qualifikatorischen Trennung im Produktionsprozess sowie von zunehmend disparaten Beschäftigungschancen für Arbeitskräfte mit unterschiedlichem Qualifikationsniveau gekennzeichnet. Dabei ist das lokale Humankapital ein wahrscheinlicher Einflussfaktor für das qualifikationsspezifische Lohnniveau sowie für das regionale Beschäftigungswachstum. Des Weiteren weisen theoretische Studien darauf hin, dass qualifikatorische Segregation eine zunehmende Polarisierung der qualifikationsspezifischen Lohnniveaus und Beschäftigung bewirken kann. Es gibt zahlreiche Studien, welche den Einfluss der lokalen Humankapitalausstattung auf qualifikationsspezifische Lohnniveaus untersuchen. Bisher gibt es allerdings kaum Analysen über die Effekte des lokalen Humankapitals auf die Beschäftigungsentwicklung in unterschiedlichen Qualifikationsgruppen. Auch eine empirische Evidenz für den möglichen Einfluss der qualifikatorischen Segregation auf die qualifikationsspezifische Beschäftigungsentwicklung ist bislang nicht vorhanden. In dieser Analyse werden die Effekte der lokalen Qualifikationsstruktur sowie der qualifikatorischen Trennung im Produktionsprozess auf das qualifikationsspezifische Beschäftigungswachstum in westdeutschen Regionen untersucht. Die Studie liefert eine erste empirische Evidenz für einen negativen Einfluss von qualifikatorischer Segregation auf das Beschäftigungswachstum von Geringqualifizierten. Zudem zeigen die Ergebnisse, dass sich ein hoher Humankapitalanteil in der regionalen Beschäftigung positiv auf die Beschäftigung von Geringqualifizierten auswirkt und keine weitere räumliche Konzentration des Humankapitals stattfindet.

**JEL classification:** R11, J21, J24

**Keywords:** regional employment growth, low-skilled employment, skill segregation

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## 1 Introduction

The development of employment in most highly developed countries is characterised by increasing inequalities across different qualification groups. While the level of high-skilled employment is steadily increasing, the demand for low-skilled workers is subject to a considerable decline (see Nickell and Bell 1995). The decreasing demand for low skills is often explained by an increased international competition promoting the specialisation on human-capital-intensive industries (see Wood 1994, 2002) and skill-biased technological and organisational changes (see Acemoglu 1998, 2002; Lindbeck and Snower 1996; Spitz-Oener 2006). However, recent studies (e. g. Autor et al. 2003) suggest that low-skilled labour might be less concerned by a decreasing demand than some types of medium-skilled labour. In particular, highly standardised medium-skill occupations, such as book- and record-keeping can be more easily substituted by technology than less standardised low-skill jobs, such as cleaning or gardening. Manning (2004) or Goos and Manning (2007) find for example that some jobs of the latter type are among the fastest growing occupations in the UK. Similar results are obtained by Spitz-Oener (2006) for Germany.

However, skill-specific employment growth may vary substantially within highly developed countries. Frequently, the local supply of human capital is regarded as a major cause for regional disparities. Several studies show that a large share of local high-skilled employment increases subsequent employment growth (e. g. Glaeser et al. 1995; Simon 1998; Simon and Nardelli 2002; Glaeser and Saiz 2004; Shapiro 2006). Based on the assumption that the productivity of less skilled workers can be positively affected by localised human capital externalities or by complementary relations between different skills there are numerous analyses investigating the effects of local human capital on the wage levels in different educational groups (e. g. Rauch 1993; Moretti 2004a; Acemoglu and Angrist 2000; Ciccone and Peri 2006). Although the effects on productivity likely impact skill-specific employment corresponding empirical evidence is rare (see Südekum 2008).

Another 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. Qualification-related structural change affects the internal qualification structure of employment at the firm level. However, rather than merely reflecting the general shift to increasing shares of high-skilled workers in overall employment, several empirical studies show also increasing levels of workplace segregation by skill (e. g. Davis and Haltiwanger 1991; Kremer and Maskin 1996; Kramarz et al. 1996; Stephan 2001; Gerlach et al. 2002). In other words, more and more firms tend to employ predominantly one specific type of qualification. Thus, labour demand is increasingly divided into firms either hiring predominantly low skills, such as providers of simple services or fast food chains, or knowledge intensive industries and services primarily recruiting high skills. 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.

Different theoretical models provide a link between qualification-related structural changes and workplace segregation by skill (Kremer and Maskin 1996; Acemoglu 1999; Duranton 2004). The models suggest that skill segregation may lead to rising wage inequalities across skill groups and also to absolute wage losses of less skilled employees. A decline in the productivity levels of low skilled workers may affect the development of low-skilled employment, in particular if wages at the lower end of the income distribution are sticky downwards. Many economists believe that increasing unemployment rates in Continental Europe, where wages are supposed to be relatively inflexible, can be traced back to the same causes (e. g. rising disparities in the skill-specific productivity levels) as the increasing wage inequalities in Anglo-Saxon countries (e. g. Krugman 1994; Freeman 1995).

So far empirical evidence on the possible effects of skill segregation on qualification-specific wages or employment as suggested by theoretical models is still lacking. This analysis provides first empirical results on the impact of segregation on the development of skill-specific employment focussing in particular on the employment prospects for workers without formal vocational education. The extent of skill segregation in the production process is assessed at the regional level, which sets this analysis further apart from previous studies investigating skill segregation only at the national level. Furthermore, this study provides evidence on the effects of the local skill composition on qualification-specific employment growth. Most previous studies that investigate the impact of human capital on regional employment growth do not differentiate between qualification levels. So far, analyses examining human capital externalities or the impact of complementarities on different skill groups tend to focus on wages. The results show that the local endowment with human capital is an important determinant for skill-specific employment growth in West German regions. Moreover, the findings reveal that skill segregation is marked by pronounced regional disparities and high regional levels of segregation negatively impact low-skilled employment growth.

Assuming a close connection between the effects of skill segregation and skill composition on skill-specific employment prospects, this analysis treats both issues simultaneously. For instance, workplace segregation by skill may prevent knowledge transfers or other types of human capital externalities to benefit less skilled employees. Moreover, if firms tend to create more and more qualification-specific jobs this should reduce the degree of substitutability between skills. Hence, there is a likely link between the existence of localised human capital externalities, skill complementarities and segregation by qualification levels. It is, however, beyond the scope of this analysis to distinguish different effects of human capital on qualification-specific employment or to establish a direct link to skill segregation.

The rest of the paper is organised as follows. The next section presents briefly the relevant literature dealing with local human capital externalities, skill complementarities and skill segregation in the production process. The data set is introduced in Section 2 and Section 4 discusses the segregation measures used in this paper and

provides a descriptive overview on the spatial pattern of skill segregation in West Germany. The specification of the empirical model and the estimation results are outlined in Section 5. Finally, Section 6 concludes.

## **2 Literature**

### **2.1 Human capital externalities and skill complementarities**

The local endowment with human capital may affect skill-specific productivity levels and employment growth in different ways. According to Lucas (1988) knowledge spillovers, generated by formal and informal interaction between people, are a possible explanation for persisting differences in the economic development across countries. Empirical studies find that a significant part of knowledge transfers decreases rapidly in space (e. g. Audretsch and Feldman 2003). Hence, human capital may raise the local level of productivity through localised externalities. Knowledge may transfer from skilled worker to skilled worker, but also between skilled and unskilled workers. Theoretical results obtained by Jovanovic and Rob (1989) or Glaeser (1999) show for example that spatial proximity between high- and low-skilled workers increases the chances for the low-skilled to learn from the high-skilled workers.

Furthermore, Acemoglu (1996) shows theoretically that the wage level of less skilled workers may be positively affected by pecuniary human capital externalities that arise irrespectively of the existence of knowledge transfers. This result is based on the assumption that human capital and physical capital are complements. Due to asymmetric information between firms and individual workers an employer cannot precisely assess the individual skill levels of potential workers beforehand. Investments in production technology, however, are made before staffing. As a consequence, firms adapt their production technology to the qualifications available on the labour market. If the share of skilled workers is high firms tend to invest more in production technology. Hence, new and modern production technologies, that are initially implemented to exploit complementarities with human capital, can raise the productivity of less skilled workers as well.

Another possible explanation for a positive impact of local human capital on wages and employment prospects of less skilled workers is a complementary relation between different skills in the production process. According to simple demand and supply side considerations the relative supply of imperfectly substitutable production factors determines their marginal productivity. Hence, if high skilled workers are locally abundant, less skilled workers are relatively scarce, which brings them higher pay than identically skilled workers in a less skilled region (e. g. Moretti 2004a; Südekum 2008).

There are several studies investigating the effects of human capital on local labour markets. Most of these analyses estimate the effects of local high-skilled employ-

ment on qualification specific wages.<sup>1</sup> Some studies, such as Rauch (1993) or Moretti (2004a), find significantly positive effects on wages. In contrast, the results obtained by Acemoglu and Angrist (2000) or Ciccone and Peri (2006) suggest that the impact of local human capital is rather weak. Until now, there is hardly evidence on the effects of local human capital on skill-specific employment growth. As an exception Südekum (2008) estimates the effect of the share of high-skilled employment on qualification-specific employment growth in Western German regions. He finds a positive effect of the percentage of workers with tertiary education on low- and medium-skilled employment growth, but not on employment growth of the high-skilled. Because of the latter result he concludes that skill complementarities are more important than knowledge spillovers. Moretti (2004a) found both, spillovers and skill complementarities, to be relevant for skill-specific wage levels.

Overall, most studies that investigate the impact of human capital on regional employment growth do not differentiate between qualification levels. Analyses that consider different skill levels tend to focus on wages, but do not regard possible influences on skill-specific employment prospects.

## **2.2 Human capital, skill segregation and employment growth**

There are different theoretical approaches that link rising levels of skill segregation to increasing inequalities in qualification-specific employment prospects (e. g. Kremer and Maskin 1996; Acemoglu 1999; Duranton 2004). While skill segregation may raise the productivity among skilled workers, it may negatively impact the productivity level at the lower end of the skill distribution. Although the mechanisms differ substantially, the models have in common that skill segregation in highly developed countries is closely related to the proceeding internationalisation of labour markets, technological and organisational changes as well as the skill structure in labour supply.

Kremer and Maskin (1996) propose a model that accounts for a simultaneous increase in skill segregation and wage inequality between qualification groups, as well as for an absolute decline in low-skill wages. Therefore, the model offers skill segregation as a reasonable explanation for the development of qualification-specific wage levels as documented for example by Katz and Murphy (1992) for the U.S. labour market. The model is based on matching complementarities between pairs of workers that join to perform specific tasks. 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 of qualification requirements between the

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<sup>1</sup> A more detailed overview on the literature dealing with the effects of local human capital on skill-specific wages is provided for example by Moretti (2004b), Duranton (2006) or Halfdanarson et al. (2008).

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 between the tasks and on the heterogeneity in the firm's skill structure. 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. Furthermore, Kremer and Maskin (1996) argue that pressures for more equal pay across skill groups are higher within firms than between firms. As a consequence, this may reduce the output of firms with heterogeneous skill structures and it may cause high-skill workers to sort into segregated firms increasing the level of workplace segregation by skill and qualification-specific wage inequalities.

While the model from Kremer and Maskin (1996) requires an increasing dispersion in the skill distribution on the labour market, an absolute increase in the supply of high-skills is sufficient to promote skill segregation in the models developed by Acemoglu (1999) and Duranton (2004). Acemoglu (1999) proposes a search theoretic model where human capital is assumed to be complementary to physical capital. Firms are not able to assess precisely the skills of potential employees beforehand because of information asymmetries. Hence, they adapt the production technology to the skills available in the labour market pool. When the supply of high 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 qualification levels make it easier for firms to distinguish individual skill levels, a large share of human capital raises the probability to employ a high-skilled person. Hence, when the probability to hire a high-skilled person increases, more and more firms tend to direct investments into technologies suitable to more qualified workers only. This leads to the exclusion of low-skilled workers from modern production technologies and processes. Thus, compared to a production employing various qualification levels, low-skilled workers in segregated firms may suffer even absolute wage losses while the productivity of high skills increases.

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 qualities of the intermediate and final good have to comply, the quality standard in a production system is determined by the final good producer. Furthermore, the grade of the produced good determines the complexity of the production technology and, therefore, the type of qualification that is required for producing this good. Hence, aggregate production in an economy comprises vertical production systems that differ by the complexity of the production process and the workers' skill level. There are two opposing forces working for or against segregation 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 total production to be segmented into vertical production systems that differ by the qualification levels of employees and the corresponding level of technology. Duranton (2004) argues that the crucial mechanism in the model is one of biased-technical change. Because of less modern production techniques the productivity in low-skill production systems is likely to fall below the pre-segmentation level. The model allows for the coexistence of several production systems comprising various skill levels. The least skilled production system may vanish when its productivity level falls below the reservation wage and the least skilled workers are released into unemployment.

All three models introduced above have in common that changes in the qualification structure may generate segregation by skill, which may lead in turn to rising wage inequalities across skill groups and even to absolute wage losses of less skilled employees. As a consequence, employment levels at the lower end of the skill distribution are likely affected by increasing levels of workplace segregation by skill via declining productivity of low-skilled. There are several studies documenting increasing levels of skill segregation in highly developed economies, such as the US, France or Germany (Davis and Haltiwanger 1991; Kremer and Maskin 1996; Kramarz et al. 1996; Stephan 2001; Gerlach et al. 2002). However, although the theoretical results point to a possible influence of skill segregation on qualification-specific productivity and employment corresponding empirical evidence is still lacking. Since workplace segregation by skill may prevent knowledge transfers or other types of human capital externalities to benefit less skilled employees, there are likely links between localised knowledge spillovers, pecuniary externalities or skill complementarities and skill segregation. It is, however, beyond the scope of this analysis to investigate these links in detail.

### 3 Data

This study investigates qualification-specific employment growth in West German regions from 1993 to 2006. Due to the specific economic development in East Germany during the transition process after the reunification and because of structural differences in skill levels that are inherited by different education systems in the formerly separated states East German regions are excluded from this analysis. Overall, the cross-section comprises 74 planning regions<sup>2</sup> in West Germany. Planning regions are functional areas that comprise several counties (NUTS 3 regions) and are defined mainly on the basis of commuting patterns. Hence, planning regions provide a suitable delimitation of labour market areas including most relevant proc-

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<sup>2</sup> Planning regions (“Raumordnungsregionen”) as defined by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR).

esses for the purpose of this investigation such as job search, recruitment of workers and adjustment of production technology to skill-specific labour supply.

Regional employment growth is differentiated by three levels of education: un- or low-skilled (no formal vocational qualification), medium-skilled (completed apprenticeship) and high-skilled (university degree). The employment data used in this analysis are taken from the official employment statistics of the Federal Employment Agency, which covers the full population of employees that are subject to social security contributions. The data are highly reliable and refer to workplace location. However, the statistic does not cover civil servants or self-employed persons. Moreover, the employment statistics provide information for several explanatory variables included in this analysis, such as the regional sector composition and firm-size structure of employment as well as further regional employment characteristics, i. e. wage levels, gender and age structures that are additionally applied to compute wage levels that are adjusted to the characteristics of the regional labour force.

In this study the regional level of skill segregation is assessed by a measurement based on the formal qualification of workers and their distribution across workplaces. For this purpose the Establishment History Panel of the Institute for Employment Research (IAB) offers annual plant level data on employment by educational attainment. The dataset contains detailed information on all establishments in Germany with at least one employee liable to social security from 1993 to 2005. Applying a region identifier the information on establishments is aggregated to the regional level.

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. Finally, 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 employment structure by branches during that period might be underestimated. Therefore, the regression analysis will be additionally conducted on a data subset constraining the observation period by the years before 1998.

## **4 Skill segregation**

### **4.1 Measuring skill segregation**

In the literature different measures of segregation by skill are applied. Frequently the between- and within-plant wage dispersion serves as an indicator for skill segregation (e. g. Davis and Haltiwanger 1991; Kremer and Maskin 1996; Karmariz et al. 1996). In this study, however, a more direct measurement of skill segregation via the formal qualification of workers is preferred. More precisely, the measure shall assess the degree of workplace segregation between skilled and unskilled workers,

i. e. workers with and without formal vocational education. Economic and sociological literature provides different measures for group-specific segregation.<sup>3</sup> This analysis applies two different segregation measures: the so-called Duncan index and the co-worker index. The Duncan index, also called index of dissimilarity, was introduced by Duncan and Duncan (1955) and is frequently used in literature as a measure for group-specific segregation:

$$D_r = 0.5 * \sum_i \left| \frac{N_{ir}^u}{N_r^u} - \frac{N_{ir}^s}{N_r^s} \right|, \quad 0 \leq D_r \leq 1 \quad (1)$$

where  $N_{ir}^u$  ( $N_{ir}^s$ ) denotes the number of full-time unskilled (skilled) employees in plant  $i$  and region  $r$ . The Duncan index  $D_r$  gives the proportion of low-skilled employees that has to be redistributed among plants in order to get identical shares of unskilled and skilled employees in each firm  $i$  in region  $r$ . Thus, in the case of “no segregation” the Duncan index is equal to zero. In contrast, a value of one indicates complete segregation.

The co-worker index, introduced by Hellerstein and Neumark (2008), assesses the extent to which unskilled workers are more likely than skilled workers to share a common workplace with other unskilled workers. The co-worker index  $C_r$  is defined as the difference between the so-called isolation index  $I_r$  and the exposure index  $E_r$ :

$$C_r = I_r - E_r, \quad \text{where} \quad I_r = \frac{1}{N_r^u} \sum_i \frac{N_{ir}^u - 1}{N_{ir}^u + N_{ir}^s - 1} * N_{ir}^u \quad (2)$$

$$\text{and} \quad E_r = \frac{1}{N_r^s} \sum_i \frac{N_{ir}^u}{N_{ir}^u + N_{ir}^s - 1} * N_{ir}^s$$

The isolation index equals the average percentage of unskilled co-workers of an unskilled employee while the exposure index equals the average percentage of unskilled co-workers of a skilled employee.

The difference between the Duncan index and the co-worker index, that is most relevant for this analysis, is that the former is scale invariant while the latter is not. In other words the Duncan index is insensitive to changes in the regional skill structure while the co-worker index is affected by a shift in 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 skilled employees in the labour force keeping constant the number of unskilled employees increases segregation level of unskilled employees. Following this argument, the co-worker index is the more appropriate to assess the degree of

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<sup>3</sup> See for example Flückiger and Silber (1999) for an overview and discussion of different segregation measures.

skill segregation. However, there are likely structural differences in the changes of the regional skill composition. Agglomerated areas for example are likely to attract comparatively more human capital than rural areas. In order to exclude such effects the Duncan index is applied as an alternative measure.

Both measures assess group-specific segregation, i. e. workplace segregation of unskilled and skilled workers. 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 (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 segregation are assessed 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 a 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.<sup>4</sup> Hence, the relevance of joint work processes including academically skilled 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 (medium-skilled) is very heterogeneous. Overall, the importance of cooperation between university graduates and unskilled workers in the production process may be low compared to joint work of less diverse skill groups, as for 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.

Overall, there are four alternative segregation measures applied in this analysis: the Duncan index and the co-worker index applying two different notions of skilled workers (Variant 1 and Variant 2), respectively.

## 4.2 Skill segregation in Western German regions

Table 1 displays the levels of skill segregation computed with the four alternative segregation measures in West Germany as a whole and differentiated by area types

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<sup>4</sup> 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.

regarding the settlement structure from 1993 to 2005.<sup>5</sup> 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 all other workers). This applies to the Duncan as well as to the co-worker index.

In the case of Variant 1 firms are more specialised on employment of either high- or low-skilled workers in 2005 than they are in 1993. Regarding the second variant of skill segregation this also holds true for the Duncan index but only to a lesser extent for the co-worker index, which remains on a fairly constant level. Overall, however, this result is in line with previous findings of increasing levels of segregation by skill in developed economies. Hence, differently skilled workers, in particular high- and low-skilled employees, tend more and more to work in different firms rather than sharing a common workplace.

Distinguishing skill segregation by settlement structure reveals some differences between metropolitan, urbanised and rural areas. In both variants the Duncan index shows similar levels across region types in 1993. However, the subsequent development of skill segregation in the production process is marked by increasing disparities across different area types. In both variants, the Duncan index increases least in rural areas and strongest in metropolitan areas. According to the co-worker index, which is sensitive to relative changes in the skill shares of employment, agglomeration areas exhibit somewhat higher and rural areas slightly lower levels of skill segregation than urban areas in 1993 as well as in 2005.

**Table 1**  
**Skill segregation by settlement structure in West Germany, in 1993 and 2005**

	Variant 1		Variant 2	
	(low- vs high-skilled)		(low-skilled vs all others)	
	1993	2005	1993	2005
<b>Duncan index</b>				
overall	0.718	0.747	0.534	0.574
agglomerated areas	0.713	0.749	0.534	0.579
urbanised areas	0.708	0.739	0.532	0.569
rural areas	0.712	0.723	0.530	0.559
<b>Co-worker index</b>				
overall	0.504	0.558	0.247	0.250
agglomerated areas	0.515	0.568	0.246	0.254
urbanised areas	0.469	0.533	0.248	0.248
rural areas	0.425	0.478	0.240	0.231

Source: Own calculation.

<sup>5</sup> The typology of settlement structure (agglomerated, urbanized and rural areas) is based on the criteria population density and size of the regional centre and has been developed by the Federal Office for Building and Regional Planning (BBSR). For details see URL: [http://www.bbr.bund.de/raumordnung/europa/download/spesp\\_indicator\\_description\\_may\\_2000.pdf](http://www.bbr.bund.de/raumordnung/europa/download/spesp_indicator_description_may_2000.pdf).

Regarding segregation levels across planning regions all alternative measures are subject to a significant variation across regions. Table 2 shows the mean, the standard deviation as well as the three top and the three bottom levels of regional skill segregation for the four alternative measures in 2005. There is a slight difference in the rank order of the regional segregation levels between the alternative segregation measures. In most cases, however, regions that are marked by a relatively high (low) segregation level according to one measure exhibit relatively high (low) levels using the alternative measures as well. The regions Ingolstadt and Oldenburg are amongst the three top end regions while Braunschweig and Main-Rhön belong to the three regions at the bottom end in all four cases, respectively. 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. By contrast in Oldenburg 84 % of unskilled workers would have to swap their workplace with high-skilled workers in other firms. In terms of the co-worker index, it is nearly twice as likely that low-skilled workers share a common workplace with other low-skilled workers in Ingolstadt as compared to low-skilled workers in Main-Rhön. The differences between minimum and maximum levels of segregation are about equally large when regarding the segregation between the low-skilled and all other employees.

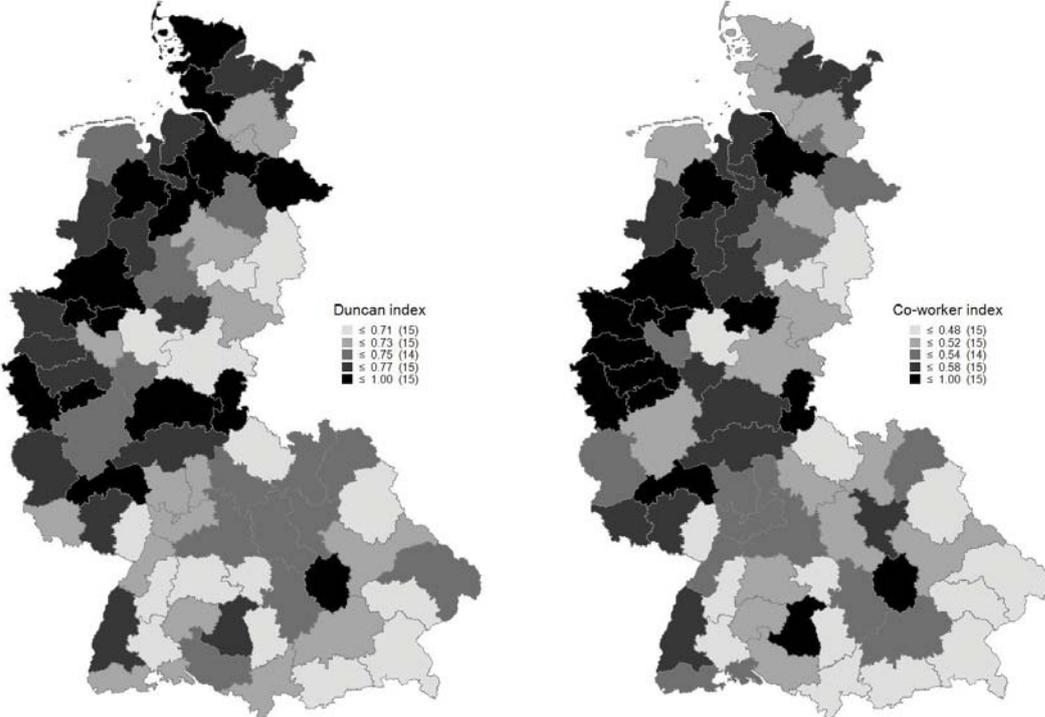
**Table 2**  
**Skill segregation in Western German regions, 2005**

		Duncan index		Co-worker index
<b>Variant 1 (low- vs high-skilled)</b>				
mean		0.736		0.522
std. deviation		0.046		0.059
top 3				
1.	Oldenburg	0.837	Ingolstadt	0.665
2.	Ingolstadt	0.836	Oldenburg	0.641
3.	Hamburg-Umland-Süd	0.820	Bonn	0.618
bottom 3		...		...
72.	Landshut	0.639	Landshut	0.407
73.	Main-Rhön	0.586	Braunschweig	0.399
74.	Braunschweig	0.567	Main-Rhön	0.364
<b>Variant 2 (low-skilled vs all others)</b>				
mean		0.569		0.241
std. deviation		0.041		0.036
top 3				
1.	Ingolstadt	0.685	Osnabrück	0.335
2.	Hamburg-Umland-Süd	0.655	Oldenburg	0.331
3.	Oldenburg	0.653	Ingolstadt	0.324
bottom 3				
72.	Main-Rhön	0.474	Göttingen	0.183
73.	Landshut	0.452	Main-Rhön	0.178
74.	Braunschweig	0.440	Braunschweig	0.143

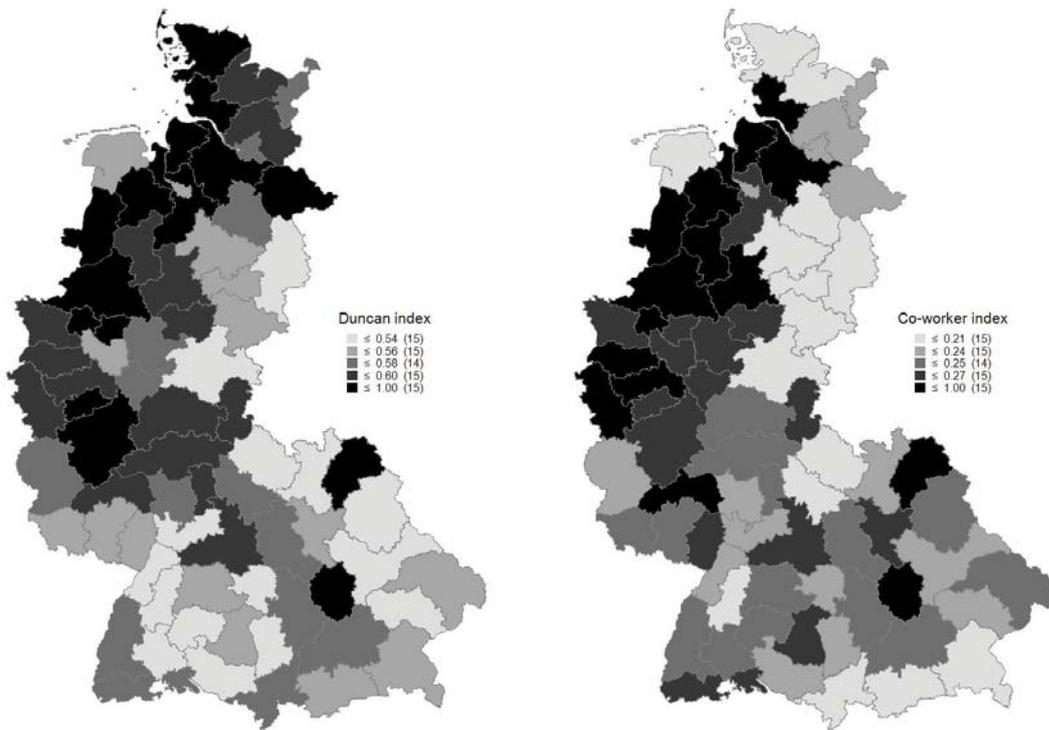
Source: Own calculation.

Figures 1a and 1b presents the regional distribution of segregation levels in 2005 measured by both indices and segregation variants. Except for some planning regions, the spatial pattern of skill segregation is quite similar in all four cases. Regardless the variant of skill segregation and the measurement applied segregation levels are relatively high in the north and in the west of Western Germany. Along the eastern and southern boundaries the degree of skill segregation tends to be comparatively low. Overall, the results indicate that regions in Western Germany are marked by pronounced disparities in the level of skill segregation.

**Figure 1a**  
**Regional levels of segregation between low-skilled and high-skilled employees**



**Figure 1b**  
Regional levels of segregation between low-skilled and all other employees



## 5 Regression model

### 5.1 Specification

For estimation purposes a panel set up including observations of 74 Western German planning regions over a period of 13 years is applied. This allows controlling time-invariant region-specific effects. Applying a fixed effects panel approach reduces the omitted variable bias problem, caused by unobserved region-specific characteristics that correlate with employment growth. The impact of the local abundance of human capital and the level of skill segregation on qualification-specific employment growth is investigated by estimating the following regression model:

$$\frac{N_{qrt} - N_{qr(t-1)}}{N_{qr(t-1)}} = \alpha + \sum_{q=1}^3 \beta_q E_{qr(t-1)} + \gamma S_{r(t-1)} + \sum_{z=1}^Z \delta_z X_{zr(t-1)} + \tau_t + \kappa_r + \varepsilon_{qrt} \quad (3)$$

The term on the left hand side represents skill-specific employment growth, where  $N_{qrt}$  denotes the number of employees with educational level  $q$  (=unskilled, medium-skilled or high-skilled) in region  $r$  and year  $t$ . Equation (3) is estimated for each specific skill group separately. The explanatory variables of main interest in this analysis are the employment shares by the skill level  $E_{qr(t-1)}$  entering simultaneously in each regression and the level of skill segregation  $S_{r(t-1)}$ , which is approximated by the alternative measures (the Duncan index and the co-worker index computed for Variants 1 and 2, respectively) in turn. Furthermore, the model includes a set  $Z$  addi-

tional control variables  $X_{zr(t-1)}$  as well as time dummy  $\tau_t$  and a region dummy  $\kappa_r$ . The random error term is represented by  $\varepsilon_{qrt}$ .

The set of additional control variables comprises the regional sector and firm-size structure as well as a neutralised level of local wages.<sup>6</sup> The local firm-size structure enters into the model as the regional employment shares that small (less than 50 employees), medium (50 to 249 employees) and large (250 and more employees) firms hold of the overall regional employment. Furthermore, the regional sector structure is controlled by the inclusion of the regional employment shares of 28 different sectors.

The neutralised wage levels represent the residuals obtained from cross-sectional regressions of the (log) wage level in each year on several characteristics of the regional workforce including the employment structure with respect to skills, sectors, firm-sizes, part-time, age and gender as well as the number of employees per square kilometres. The latter variable was included to control for structural differences in wage levels or the costs of living between agglomerated regions and less densely populated areas. The residuals can be interpreted as deviation from the expected wage level given by the local characteristics of the work force. Therefore, the neutralised wage levels are adjusted for region-specific features of the workforce and characteristics of the regional economy.<sup>7</sup>

Two specific problems arise in the estimation of Equation (3).<sup>8</sup> The first one concerns the heterogeneity in sizes of the observation units, and hence their relative importance for average growth rates. Since the employment levels differ substantially across regions, the same absolute change in employment implies very different changes in employment growth rates. Furthermore, little absolute changes may boost employment growth in small regions inducing model inherent heteroscedasticity. To circumvent this problem, Equation (3) is estimated with weighted least squares (WLS) using the square root of the regional employment shares as weights:

$$w_{qrt} = \sqrt{\frac{N_{qrt}}{N_{qt}}} \quad (4)$$

The second problem refers to the interpretation of the estimated effects of the skill-specific employment shares on regional employment growth. As the shares add up to unity the inclusion of all shares would lead to perfect multicollinearity. Commonly, one reference category is left out and the coefficients of the included share variables

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<sup>6</sup> These factors are found to be influential on regional employment growth for example by Möller and Tassinopoulos (2000), Blien (2003) or Südekum et al. (2006).

<sup>7</sup> A similar procedure was applied for example by Südekum and Blien (2004) or Südekum et al. (2006).

<sup>8</sup> Both problems and the corresponding approaches (similar to those applied in this paper) are discussed more deeply by Möller and Tassinopoulos (2000) or Südekum et al. (2006).

show the effects in relation to the reference variable. Measuring the effects in reference to an arbitrarily omitted category would not provide a feasible interpretation for the purpose of this study. This problem can be solved by imposing an identifying linear restriction on the corresponding coefficients:

$$\sum_{q=1}^3 \frac{N_{qr}^T}{N_q^T} \beta_q = 0 \quad (5)$$

where  $N_{qr}^T$  and  $N_q^T$  denote the average employment level by skill group  $q$ , in region  $r$  and West Germany, respectively, over observed period  $T$ . Using this constraint on the coefficients,  $\beta_1$  to  $\beta_3$  can be interpreted as the effect of the regional deviation of the employment shares to the average employment shares of the respective skill groups over all regions. This method represents a normalisation of the coefficients that does not affect the other estimators.

As outlined above, changes in the sector composition might be underestimated due to data restrictions for the years before 1998. Furthermore, it might be suitable appropriate to estimate Equation (3) for a sub-period in order to check for the stability of the estimated effects over time. In 1998 overall employment started to rise again after a decline over several years. Thus, it seems reasonable that the regressions are applied to the full time period from 1993 to 2006 and another shorter time period from 1998 to 2006.

Since regional employment growth may be affected by the economic development of neighbouring regions the estimation model maybe miss-specified due to the assumption of observing independent entities. Significant spatial dependence that is not considered in the model leads to inefficient estimates if spatial autocorrelation is restricted to the error term (spatial error dependence) or inefficient and biased estimates if there is direct spatial interaction in the endogenous variable (spatial lag dependence).<sup>9</sup> Because of using functional planning regions the occurrence of spatial dependence is less likely. However, the issue of spatial autocorrelation is considered in further robustness checks.

## 5.2 Results

A summary of the most important results obtained by estimating Equation (3) is presented in Table 3 and Table 4. The tables include both, the estimation results comprising the time period from 1993 to 2006 (upper part) as well as the shorter one from 1998 to 2006 (lower part). Only the coefficients of the pivotal variables, i.e. the skill group shares and the segregation measures are presented in the tables.<sup>10</sup> The columns of the table refer to separate models for low-, medium- and high-skilled employment growth as dependent variables.

<sup>9</sup> See for example Anselin (1988) for details.

<sup>10</sup> The coefficients for the remaining control variables can be obtained upon request from the author.

**Table 3**  
**Estimation results including Variant 1 (low- vs high-skilled)**

	High-skilled employment		Medium-skilled employment		Low-skilled employment	
<b>Including years from 1993 to 2006</b>						
Share of high skills	-0.270 *	-0.282 *	0.253 **	0.268 ***	0.501 **	0.428 ***
	(.0121)	(0.121)	(0.071)	(0.071)	(0.128)	(0.128)
Share of medium skills	0.174 **	0.172 **	-0.039 *	-0.042 *	0.270 **	0.281 **
	(0.035)	(0.036)	(0.018)	(0.018)	(0.033)	(0.033)
Share of low skills	-0.449 **	-0.437 **	0.017	0.020	-1.095 **	-1.097 **
	(0.117)	(0.118)	(0.059)	(0.060)	(0.107)	(0.108)
Duncan index	-0.043	–	0.038 *	–	-0.178 **	–
	(0.036)		(0.019)		(0.034)	
Co-worker index	–	-0.014	–	0.030	–	-0.141 **
		(0.031)		(0.016)		(0.029)
<b>Including years from 1998 to 2006</b>						
Share of high skills	-1.480 **	-1.486 **	-0.108	-0.090	0.529 *	0.427
	(0.195)	(0.196)	(0.125)	(0.125)	(0.228)	(0.228)
Share of medium skills	0.421 **	0.413 **	-0.006	-0.016	0.417 **	0.454 **
	(0.054)	(0.056)	(0.031)	(0.031)	(0.056)	(0.057)
Share of low skills	-0.722 **	-0.694 **	0.066	0.091	-1.583 **	-1.659 **
	(0.187)	(0.190)	(0.105)	(0.106)	(0.192)	(0.193)
Duncan index	-0.061	–	0.021	–	-0.241 **	–
	(0.056)		(0.031)		(0.058)	
Co-worker index	–	-0.012	–	0.034	–	-0.203 **
		(0.041)		(0.023)		(0.042)

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

Source: Own calculation.

**Table 4**  
**Estimation results including Variant 2 (low-skilled vs all others)**

	High-skilled employment		Medium-skilled employment		Low-skilled employment	
<b>Including years from 1993 to 2006</b>						
Share of high skills	-0.282 *	-0.275 *	0.252 **	0.254 **	0.478 **	0.477 **
	(0.121)	(0.122)	(0.070)	(0.071)	(0.129)	(0.130)
Share of medium skills	0.166 **	0.168 **	-0.042 *	-0.033	0.256 **	0.237 **
	(0.035)	(0.035)	(0.018)	(0.018)	(0.033)	(0.032)
Share of low skills	-0.417 **	-0.426 **	0.027	-0.004	-1.038 **	-0.976 **
	(0.118)	(0.116)	(0.059)	(0.058)	(0.108)	(0.106)
Duncan index	0.019	–	0.063 *	–	-0.129 **	–
	(0.051)		(0.025)		(0.047)	
Co-worker index	–	-0.020	–	0.042	–	-0.107 *
		(0.055)		(0.028)		(0.052)
<b>Including years from 1998 to 2006</b>						
Share of high skills	-1.480 **	-1.480 **	-0.108	-0.107	0.532 *	0.514 *
	(0.195)	(0.195)	(0.124)	(0.125)	(0.228)	(0.229)
Share of medium skills	0.395 **	0.408 **	-0.013	-0.002	0.421 **	0.369 **
	(0.055)	(0.053)	(0.031)	(0.030)	(0.056)	(0.055)
Share of low skills	-0.640 **	-0.679 **	0.089	0.052	-1.595 **	-1.419 **
	(0.189)	(0.184)	(0.105)	(0.103)	(0.193)	(0.188)
Duncan index	0.057	–	0.052	–	-0.246 **	–
	(0.063)		(0.034)		(0.063)	
Co-worker index	–	-0.012	–	0.029	–	-0.286 **
		(0.075)		(0.042)		(0.078)

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

Source: Own calculation.

The results show that a large regional share of a specific skill group significantly tends to reduce employment growth in the same skill group. Over the full period from 1993 to 2006 this applies to each of the three qualification levels. Regarding the shorter time period only the corresponding coefficient of the medium-skilled is insignificant. A negative impact of a high share of human capital on high-skilled employment growth suggests that human capital externalities among the high skilled might not be strong enough to outweigh the neoclassical supply effect. The latter might emerge since high skilled workers are less productive in regions where they are relatively abundant. Hence, there is no process of regional concentration of human capital. This is also found by Südekum (2008) who investigates convergence of the skill composition across Western German districts (NUTS-3 level regions).

Furthermore, the results indicate that the development of low-skilled employment is positively affected by the presence of more qualified employees. Large employment shares of medium- and high-skilled workers have a significantly positive impact on low-skilled employment growth. This result is consistent with both time periods. There is some evidence against pronounced complementarities between skills as the impact of a high share of unskilled employment is significantly negative on high-skilled and insignificant on medium-skilled employment growth. Furthermore, there is no significant effect of a relative regional abundance of university graduates on the growth of the number of medium-skilled employees in the shorter time period. Yet, it is difficult to identify whether the positive influence of skilled labour on the development of low-skilled employment is due to knowledge transfers, pecuniary externalities or complementary relations between different skills as described by Moretti (2004a).

The results presented in Table 3 and Table 4 clearly demonstrate that skill segregation in the production process matters for the development of low-skilled employment. In both periods under consideration the coefficients of the alternative segregation measures are statistically significant and negative. Hence, skill segregation negatively impacts low-skilled employment growth. According to the estimation results for the complete time period an increase in the regional level of workplace segregation by one standard deviation (Duncan index) reduces growth of low-skilled employment in both variants by about 0.8 percentage points.<sup>11</sup>

The estimation results do not reveal notable effects of workplace segregation by skill on the employment prospects of more qualified workers. All estimated effects of skill segregation on high-skilled employment growth are insignificant. Medium-skilled employment growth is only significantly affected (0.05-level) when applying the Duncan index in the estimation on the complete time period. The theoretical results presented above also imply that skill segregation has an increasing impact on the wage

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<sup>11</sup> Regarding the co-worker index the reduction by one cross-sectional standard deviation decreases low-skilled employment by about 0.5 percentage points in the case of Variant 1 and 0.4 percentage points in the case of Variant 2.

level of more qualified workers. This may be due to increased complementarities between human and physical capital (Acemoglu 1999; Duranton 2004), or because of matching complementarities (Kremer and Maskin 1996). Alternatively, skill segregation might also lead to more intensified knowledge spillovers among high-skilled workers. However, if skill segregation promotes the productivity of more skilled workers this does not seem to translate into employment growth.

Besides estimating the effects for two different time periods, further robustness checks are conducted. The estimation results have been checked for the presence of spatial autocorrelation and for influential observations (leverage points) combining a relatively small or large growth rate with outlying values for one of the pivotal explanatory variables. In order to control for the latter, I used a procedure where Equation (3) was repeatedly estimated successively leaving out single observations. The results of the procedure closely match the estimates previously presented. Hence, there is no observation that exerts a particularly large influence on the estimates.<sup>12</sup>

**Table 5**  
**Moran's/coefficients**

Year	High-skilled employment		Medium-skilled employment		Low-skilled employment	
1994	-0.018	(-0.053)	0.036	(0.662)	-0.006	(0.101)
1995	-0.019	(-0.071)	-0.010	(0.047)	-0.071	(-0.773)
1996	0.026	(0.535)	-0.023	(-0.127)	-0.020	(-0.084)
1997	-0.160	(-1.962)	-0.064	(-0.679)	0.059	(0.978)
1998	-0.054	(-0.537)	-0.055	(-0.545)	-0.059	(-0.612)
1999	-0.026	(-0.167)	-0.173 *	(-2.146)	-0.104	(-1.206)
2000	-0.087	(-0.986)	-0.033	(-0.260)	-0.101	(-1.173)
2001	-0.040	(-0.344)	0.106	(1.598)	0.157 *	(2.285)
2002	-0.078	(-0.873)	0.004	(0.248)	-0.052	(-0.521)
2003	0.012	(0.340)	-0.037	(-0.316)	0.093	(1.413)
2004	-0.107	(-1.260)	0.009	(0.303)	0.053	(0.887)
2005	-0.099	(-1.155)	-0.039	(0.303)	-0.097	(-1.124)
2006	-0.112	(-1.315)	-0.042	(0.303)	-0.110	(-1.290)

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

Source: Own calculation.

In order to check for specification errors caused by spatial autocorrelation Moran's/coefficient is applied on the residuals obtained by estimating Equation 3. Therefore, a spatial weights matrix has to be applied, which is supposed to capture the structure of spatial dependence. The weights matrix used for the calculation of the Moran's/coefficients depicts whether regions have a common border or not, which is a frequent approach (e. g. Rey and Montouri 1999). Thus, it is checked whether the residuals of neighbouring regions are more similar than those of non-

<sup>12</sup> The results of the auxiliary estimations can be obtained upon request from the author.

neighbouring regions.<sup>13</sup> The calculated Moran's/coefficient is significant in only very few cases. Table 5 shows for example the Moran's/calculated on the basis of the cross-sectional residuals applying the Duncan index (Variant 1) as segregation measure.<sup>14</sup> Only two out of 39 coefficients are statistically significant. Hence, there is no reason to assume a severe miss-specification due to spatial autocorrelation. However, as further check an unconstrained version of Equation (3) was estimated using corrected standard errors as introduced by Driscoll and Kraay (1998). These standard errors are robust to heteroscedasticity as well as longitudinal and cross-sectional autocorrelation (see also Hoechle 2007). In comparison, the unconstrained estimations with and without robust standard errors do not produce systematically different results. Therefore, the observation units, i. e. planning regions, provide a suitable delimitation of labour market areas enclosing most relevant activities.<sup>15</sup>

## 6 Conclusions

Workplace segregation by skill may impede knowledge transfers or other pecuniary externalities arising from a relatively high level of technology to benefit less skilled employees. Moreover, if firms tend to create more and more qualification-specific jobs this should reduce the degree of substitutability between skills. Hence, there is a likely link between the existence of localised human capital externalities, skill complementarities and segregation by qualification levels. Assuming a close connection between these issues this analysis examines the effects of the local skill composition and the level of skill segregation on skill-specific employment growth simultaneously. It is, however, beyond the scope of this analysis to distinguish different effects of human capital on qualification-specific employment or to establish a direct link to skill segregation. This study investigates a cross-section of 74 West German regions focussing in particular on the employment prospects for workers without formal vocational education.

A number of analyses suggest that local human capital positively impacts the productivity levels in all skill groups. Evidence on the effects on skill-specific employment, however, is still rare. The results of this study show that a large regional share of more skilled employees positively affects the employment prospects of less skilled workers but not vice versa. That is unskilled workers profit from local high- as well as medium-skilled employment. The effect of local high-skilled employment on medium-skilled employment growth is positively significant for the complete time period from 1993 to 2006, but cannot be validated by estimating the effects for a shorter control period from 1998 to 2006. Since a relative local abundance of each

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<sup>13</sup> Because there is usually not a priori information about the exact nature of spatial dependence, the choice for the design of the spatial weight is somewhat arbitrary. See Le Gallo et al. (2003) for a more detailed discussion of the functional form of spatial weight matrices.

<sup>14</sup> The results based on alternative specifications can be obtained upon request from the author.

<sup>15</sup> The results of these test regressions can be obtained from the author upon request.

skill groups has a negative impact on itself there is no evidence for a regional concentration of employment by qualification levels. This confirms the results obtained by Südekum (2008) for West German districts.

This study provides first empirical evidence on the impact of skill segregation in the production process on the development of skill-specific employment. Though theoretical results imply that skill segregation might matter for the polarisation of wages and employment corresponding empirical evidence has been lacking so far. The results of this analysis reveal that growth of regional low-skilled employment is negatively affected by a high level of segregation by qualification levels. The negative effect of workplace segregation by skill might reflect the mechanisms described for example by Acemoglu (1999) or Duranton (2004) where employees without professional education in segregated workplaces tend to work in jobs characterised by low capital intensity and working processes of little complexity. This is because firms tend to invest more in modern production technology when they can exploit complementarities between physical and human capital. As an alternative explanation, the dampening effect of skill segregation might also consist in impediments to learning effects. As for example modelled by Jovanovic and Rob (1989) or Glaeser (1999) the presence of more qualified co-workers could positively affect the productivity of low-skilled labour through knowledge transfers. It is not possible to draw precise conclusions from this result about the exact nature of the mechanisms. However, in both cases the productivity of low-skilled employees in segregated workplaces is relatively low compared to their counterparts sharing a common workplace with more qualified colleagues, which adversely affects their employment prospects. This analysis did not find evidence for effects of skill segregation on medium- or high-skilled employment. Though skill segregation has a likely positive effect on the productivity of more skilled workers this may not have translated into employment growth.

Overall, the analysis shows that a local abundance of human capital matters for skill-specific employment growth. While it does not foster further accumulation of human capital it has a positive impact on less skilled employment, in particular on workers without formal vocational education. However, according to the estimation results there is another dimension than proximity that matters when regarding the effects of local human capital. This analysis reveals that production processes (firms) employing different qualification types foster the employment prospects of low-skilled workers. Regarding the high unemployment rates of low-skilled workers in most developed countries workplace segregation by skill is an important issue for further regional labour market research and policy. Additional research may be necessary to validate these results for example in other countries or to identify the exact mechanisms behind the effects of local human capital, skill segregation and their interplay.

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