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The role of firm-level and regional human capital for the social returns to education - Evidence from German social security data

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Abstract

This paper provides first evidence on the anatomy of human capital externalities arising from both firm-level and regional human capital. Using panel data from German social security records, both at an individual and aggregated at the plant and regional level, I estimate earnings functions incorporating measures of regional and firm-level human capital while controlling for various types of unobserved heterogeneity. The results suggest that the firm-level share of high-skilled workers generates positive, although small social returns to education for low-skilled and skilled workers but not for the high-skilled. This finding is in line with learning based theories of human capital externalities. Some estimates also suggest negative social returns for the regional shares of low-skilled workers. No such effects are found for the firm-level shares of low-skilled workers and the regional shares of high-skilled workers.

Keywords: Human capital externalities, social returns to education, error-component model
JEL Classification: D62, J24, J31, R11

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Stata 10.1 was used in all calculations. All do-files are available from the author on request. The data used in this paper can be accessed via the research data center of the Federal Employment Agency in the Institute of Employment Research in Nuremberg. See http://fdz.iab.de for details. The author would like to thank Joachim Wagner for helpful hints and overall support. All remaining errors are my own.

1 Introduction

This paper considers for the first time the importance of both regional and firm-level human capital for the existence of human capital externalities. Results based on panel data from German social security, used at the individual and aggregated at the plant and regional level, suggest significant positive effects of the firm-level share of high-skilled workers on the wages of low-skilled and skilled workers but not on the wages of high-skilled workers. However, the wage increases caused by variation in the firm-level share of high-skilled workers are often relatively small over empirically relevant shares. Some estimates also suggest negative wage effects for the regional shares of low-skilled workers. No such effects are found for the firm-level shares of low-skilled workers and the regional shares of high-skilled workers. Overall, the results suggest that learning-spillovers from high- to low-skilled workers might matter on the firm level, while no support is found for the existence of social returns to education on the regional level.

On a theoretical level, the existence of a relationship between some measure of average human capital and individual wages, even when controlling for individual human capital, typically referred to as either *human capital externalities* or *social returns to education* has been explained by a number of ideas. The first relates to "pecuniary externalities" that arise through the interaction of firms' and workers' investment decisions under imperfect information (see Acemoglu 1996 for a formal model). The basic idea may be sketched as follows: Firms investment decisions are positively influenced by the qualification level of the (regional) workforce as this allows firms to replace quitting workers more easily (see Acemoglu 1997a for a formal model) what in turns influences workers decisions to invest in human capital. The externalities arise because firms may not observe the true qualification or productivity of single workers which has two effects. First, firms use regional average human capital as an indicator when deciding on future investments. This creates a positive relationship between regional human capital and – through the fact that human and physical capital are assumed to be complements – higher wages. Second, workers and firms are matched imperfectly which means that some low productive workers are matched to workplaces with higher amounts of physical capital and higher wages than in a competitive market with perfect information. These models effectively predict a relationship between the regional supply of high-productive or high-qualified workers and average wages of all skill groups.

Another idea is an improvement of the matching-process between workers and firms. The general idea that can be traced back to Marshall's "Principles of Economics" (Marshall 1890/1961) is that a high share of workers with a certain level of education in a certain region implies a high number of jobs for workers with that qualification level. This in turn raises the likelihood of "good" worker-firm-matches and consequently productivity and wages. Note that this explanation predicts a positive relationship between the supply of workers of a certain qualification level and the wages of workers with this qualification level.

Finally, another line of theoretical reasoning leads to "non-pecuniary" or technological externalities. The basic idea here is that workers may learn from each other through interactions, learning by doing or imitation (for formal models for regional human capital see Lucas 1988, Jovanovic and Rob 1989, Murphy, Shleifer and Vishny 1991, Benabou 1996, Acemoglu 1997b, Glaeser 1999, Acemoglu and Angrist 2000; Martins and Jin 2008 provide a formal model in terms of workplace interactions). A higher share of productive or high-qualified workers enhances the likelihood of such knowledge spillovers and consequently leads to higher regional productivity and growth. If one is willing to assume that learning spillovers are more likely to occur from higher to lower qualified workers, one would expect a positive relationship between individual wages and the share of workers with a higher qualification than the respective individual.

The growing empirical literature on this subject has reached mixed results for externalities arising from regional, industry- or firm-level human capital. On the regional level, the pioneering study by Rauch (1993) uses cross-sectional data from the United States and finds evidence for externalities on the order of 3-5 percent per year of average schooling in a Standard Metropolitan Statistical Area. Acemoglu and Angrist (2000) exploit compulsory schooling and child labor laws in an instrumental variable-estimation using data from the 1960 to 1980 US-censuses. Their findings suggest insignificant returns to state wide schooling in the magnitude of roughly 1 percent per year of average schooling. Moretti (2004a) uses NLSY and census data from the US and finds external returns to the share of college graduates in a city. The effects are larger for low qualified workers but also exist for college graduates. In a similar paper, Moretti (2004b) documents external effects of the regional share of college graduates on the productivity of plants in that region. Additionally, he reports an increase in labor costs that offsets these productivity gains. Finally, Heuermann (2008) uses instrumental variables estimations on panel data from German social security and finds that the regional share of high-qualified workers raises the wages of both high- and non-high-qualified workers. Moretti (2004c) provides an overview on these and other effects of regional human capital in cities.

On the firm-level, Battu, Belfield and Sloane (2003) use cross-sectional linked-employer-employee data from the UK and find that a one standard deviation increase in the average level of schooling in a plant (equaling 1.2 years) raises individual earning by 11 percent.

Martin and Jin (2008) use linked-employer-employee panel data from Portugal and find large firm-level social returns on average wages between 14 percent and 23 percent per year of average schooling. Mas and Moretti (2009) use data from a single firm to study productivity spillovers in work-groups. They find that low-productivity workers profit from the presence of a high-productivity workers in the same work-group.

Additionally, some studies are concerned with the effects of industry wide human capital. Winter-Ebmer (1994) uses cross-sectional data from Austria and estimates external returns to education to be in the magnitude of 4 percent to 9 percent per year of average schooling. Sakellariou (2001) finds no effect of industry-wide schooling on individual wages using cross-sectional data from Guatemala. Evidence from cross-sectional data from Venezuela suggests external effects in the magnitude of 3 percent to 9 percent per year of average schooling (Sakellariou and Maysami 2004). Finally, using repeated cross-sections from the UK, Kirby and Riley (2008) find effects in the magnitude of 2.6 percent to 3.9 percent per year of average schooling.

This paper builds on the previous empirical literature and considers for the first time the effects of both regional and firm-level human capital.[1] Distinguishing between these effects may be worthwhile for a variety of reasons. First, the two types of human capital may have (theoretically) different effects: Learning and other types of technological human capital spillovers require a certain level of interaction between workers (see e.g. the theoretical model developed in Martins and Jin (2008)). As interactions between workers in the same firm can be expected to occur more frequently than interactions between workers in the same region, firm-level human capital seems more relevant than regional human capital

[1] I ignore the industry level due to data constraints. For the firm and regional level, the available measures are calculated using data on the *population* of workers and consequently do not suffer from sampling error. Such measures are not available for the industry level.

in this case. Acemoglu's (1996, 1997a) models are explicitly related to regional human capital. In fact, relating his models to firm-level human capital seems rather far-fetched as the models' mechanisms are driven by firms' imperfect information about the supply of high-productivity workers. This lack of information seems unlikely with respect to the firm's own workforce. For arguments relating the external returns to education to improved matching of workers and firms, one might argue that regional human capital, capturing e.g. the number of jobs for high-qualified workers, may be more relevant than firm-level human capital. Note, however, that I do not suggest that *only* firm-level human capital matters for learning and *only* regional human capital matters for matching as e.g. learning may also occur between firms and workers might improve job matches within firms by moving in a different department. Nevertheless, there is a clear possibility that the effects of the two types of human capital may differ.

A second point that calls for a simultaneous consideration of these types of human capital is the fact that firm-level and regional human capital are most likely (imperfectly) positively correlated. Econometrically, this correlation implies that studies focusing on only one type estimate a mixture of the true effects of both types of capital. Such a correlation is likely to be relevant as there are for instance high-tech clusters with many firms employing a large number of high-qualified workers as well as rural areas with many firms employing less qualified workers. However, the correlation is unlikely to be perfect as there are also high-tech firms in otherwise rural counties and low-qualification firms, like the local fast-food-restaurant, in high-tech clusters. In fact, a look in the data used in this study (see section 2 for details) reveals that the correlation between the firm-level and regional shares of low- and medium-skilled labor are around 0.2 while the correlation for high-skilled labor is around 0.4. Finally, as the previous literature has documented the existence of effects for both firm-level and regional human capital, it is of interest to see whether these are in fact two different effects or rather one single effect which is identified on different levels of aggregation.

In this paper, I use panel data from German social security records at the individual and aggregated at the firm[2] and regional level. I estimate standard wage functions augmented by various measures of firm-level and regional human capital while controlling for various types of unobserved heterogeneity and time-varying confounders. Additionally, I look at differences in the social returns to human capital for workers with different levels of individual education.

The remainder of this paper is organized as follows: Section 2 describes the social security data used. First descriptive evidence using non-parametric regressions is found in section 3. The econometric model is outlined in section 4, its results are presented in section 5. Section 6 concludes.

2 Data

The individual level data used in this study comes from the so called employment panel of the Federal Employment Agency (*BA- Beschäftigtenpanel*) for the years 2003 to 2006. Specific information on an earlier version of the employment panel can be found in Koch and Meinken (2004), the current version is described (in German) in Schmucker and Seth (2009).

The individual data originates from social security information and is collected in the

[2]"Firm" in this context refers to the local production unit, the plant. "Firm" and "plant" are used alternatively in this paper.

so called *employee history* by the Federal Employment Agency.[3] In Germany, employers are obliged by German law to deliver annual information on their employees, as well as additional information at the beginning and end of an employment, to social security. These notifications are used to calculate pensions, as well as contributions to and benefits from health and unemployment insurance. The data contain information on the begin and end of employment, daily wages, a person's age and sex, as well as several variables collected for statistical purposes, e.g. education or nationality. The resulting spell data cover approximately 75 - 80% of the German workforce, excluding free-lancers, the self-employed, civil servants and (unpaid) workers helping in family businesses (Koch and Meinken 2004, p. 317).

The employment panel is drawn from the employee history in a two step procedure. First, all persons born on one of seven specified dates are selected. As the German social security number is tied to the date of birth and does not change over time, it is possible to track those persons over time. Additionally, entries in and exits from the labor force are automatically covered by this procedure as new entrants born on one of these dates replace persons leaving the labor force. In a second step, the panel is formed by drawing four cross-sections per year – on the last day of March, June, September and December respectively – from this data. Finally, if a person receives unemployment benefits or is in an active labor market program on one of those days, an artificial observation indicating this fact is generated from other data sources of the Federal Employment Agency. The resulting panel is unbalanced due to entries into and exits from the labor force. However, there is no missing information due to non-response. As most records in the data are based on the annual notifications to social security, which means that there is essentially no wage

[3] More information on person-level data from German social security records can be found in Bender at al. (2000).

variation within the year for these observations, this study uses only the last observation available for each year.

The person level data is combined with firm information that is formed by aggregating social security data on the plant level. The plant data provide information on the structure of the respective workforce regarding education, age and occupational position, the plant size and the industry affiliation of the respective plant.

The data also contains information on the county (*Kreis* or *Kreisfreie Stadt*) where the worker's employer is located. A German *Kreis* is similar to the US counties in the hierarchy of public administration. It is the third highest level of administration, placed above the communal level, but below the Federal States (*Bundesländer*) and the country administration, the *Bund*. A county usually covers several towns or villages (*Kreis*) or one large city (*Kreisfreie Stadt*). In two cases, *Berlin* and *Hamburg*, it is also identical to the Federal State (*Bundesland*). The average population of a county (in 2003) is 192,502 with the smallest county being the city of *Zweibrücken* with a population of 35,677 and the largest county being *Berlin* with a population of 3,391,515. Note at this point that Berlin is not in the sample as I focus on West Germany. Given that the economic conditions in East and West Germany were still very different at least at the beginning of the Millennium (see e.g. Barrel and te Velde (2000), Franz and Steiner (2000) and Klodt (2000)), focusing on West Germany allows me to ignore the effects of the East German transformation process and allows for a cleaner identification of the human capital effects. To capture the amount of regional human capital, I again use social security records, in this case aggregated at the county level and provided by the statistics department of the Federal Employment Agency. This data can be accessed through the website www.regionalstatistik.de which is operated by the Federal Statistical Office and the Statistical Offices of the Federal States.

Human capital on the firm or regional level is measured by the shares of low-skilled, skilled and high-skilled workers in the total number of workers in the respective plant or region. Low-skilled workers are defined as workers without post-school training, regardless of the amount of secondary schooling, while skilled workers have completed vocational training and high-skilled workers are those with an academic degree. All values are calculated without the education of the individual under observation to address potential endogeneity concerns, for instance raised in Angrist and Pischke (2009, pp. 193-197). The measures of individual human capital are formed in an identical way.

To arrive at the estimation sample, I first drop persons younger than 25 and older than 60 to avoid problems with ongoing education and early retirement. I further restrict the sample to regular, full time workers, dropping trainees, home and part-time workers as well as the unemployed. Wages that are top-coded at the contribution limit to social security are imputed using a Tobit-based imputation as described in Gartner (2005). Note that the wages of low-skilled and skilled workers are considerable less affected by censoring than those of high-skilled workers. This fact should be kept in mind when looking at the results for the latter. Finally, I drop the top/bottom 1% of the wage distribution to control for outliers and keep only West-German men to avoid problems with gender-specific labor market participation and the large economic differences between East and West Germany. The resulting sample covers 583,078 person-year-observations from 179,501 individuals of which 26,219 individuals (76,704 observations) are low-skilled, 130,920 (422,882) are skilled and 26,696 (83,492) are high-skilled workers. Individuals are observed for 3.25 periods on average. There are at least 78 individuals in each county with an average of 620 individuals. Descriptive statistics can be found in table 1.

(Table 1 about here.)

Figure 1 displays the distributions of both firm-level and regional human capital observed in the sample. Note that most workers are employed in firms with relatively low shares of both high- and low-skilled workers, while most firms have a considerable share of skilled workers. This finding is exactly what can be expected in Germany with its generally skilled workforce. Note further that there is considerable more variation in the firm-level than in the regional shares of the skill-groups which – relatively unsurprisingly – implies that firms are more heterogeneous than regions with respect to human capital.

(Figure 1 about here.)

3 Descriptive evidence

To get a first impression on the relationship between individual wages and regional and firm-level human capital, figures 2 to 4 show non-parametric regression estimates based on local polynomial regressions for all workers and various skill groups. Starting with the relationship between the regional and firm-level shares of low-skilled workers displayed in figure 2, one notices a relatively similar negative relationship between the firm-level share and individual wages for all skill groups. This result is in line with learning based explanations of human capital spillovers if one assumes that knowledge spillovers are unlikely to occur from lower to higher qualified workers.

(Figure 2 about here.)

The relationship between wages and the regional share of low-skilled workers looks more complicated. For low-skilled workers, we observe a negative relationship which is inconsistent with explanations of human capital externalities involving matching efficiency where a higher number of low-skilled jobs should lead to higher wages for the low-skilled through better matches. It is, however, consistent with a theory of regional knowledge spillovers which are less likely the higher the share of low-skilled workers. For skilled workers, we observe a U-shaped relationship with a relatively flat bottom between shares of 0.2 and 0.25. While the negative part of the relationship could be explained by reasoning similar to that for the low-skilled workers, the increase at higher shares of low-skilled workers is inconsistent with both learning and matching based explanations of human capital externalities. For high-skilled workers, we observe again a negative relationship that is relatively flat at first and quickly declines when the share of low-skilled workers exceeds 0.25.

Looking at the firm-level shares of skilled workers displayed in figure 3, we see a positive relationship with the wages of the low-skilled which is consistent with an explanation that involves learning and knowledge spillovers from higher to lower qualified workers. For the wages of skilled and high-skilled workers, we observe a hump-shaped relationship with a relatively flat top. The decline is stronger and begins at lower shares for skilled than for high-skilled workers which may be related to skill premia at the firm-level that vanish with an increasing abundance of the respective skill group.

(Figure 3 about here.)

At the regional level, we see an unequivocally negative relationship for all skill groups. This relationship is relatively stronger for low-skilled and skilled workers than for high-skilled workers which is consistent with a market based explanation where wages are driven down by an increase in labor supply. The somewhat weaker effect for high-skilled workers could be related to smaller possibilities to substitute high-qualified with lesser qualified labor but this reasoning is mostly speculative.

Finally, consider the results for the regional and firm-level shares of high-skilled workers displayed in figure 4. Here, we observe a positive relationship between the firm-level shares and the wages of low-skilled and skilled workers. This result is again consistent with productivity enhancing learning-spillovers from higher to lower educated workers. For high-skilled workers, the estimates suggest a hump shaped relationship with a relatively flat top which is similar to the relationship found for the monthly wages of skilled or high-skilled workers and the firm-level share of skilled workers.

(FIGURE 4 ABOUT HERE.)

For the regional shares of high-skilled workers, the results show a unequivocally positive relationship with the wages of all skill group. Note that this result is consistent with both theories of regional knowledge spillovers and with Acemoglu's (1996) model of pecuniary externalities, but does not seem to fit matching based theories very well. While a higher number of high-qualified jobs in a specific region might improve the job-matching of high-qualified workers, there is no compelling reason to assume that the job-matching-process of low-skilled or skilled workers should be improved by a higher number of high-qualified jobs.

To sum up, the initial conjecture that there may be differences in the relationship between wages and regional and firm-level human capital respectively seems to be supported by the data. Some general conclusions can be drawn from the results. First, every worker regardless of his educational level profits from the presence of higher educated workers in the same firm. This finding is consistent with a story where lower skilled workers learn from higher skilled workers and become more productive as a result. Second, with the exception of low-skilled workers, one usually observes a hump-shaped relationship with a relatively large flat top between wages and the firm-level shares of equally or slightly less qualified workers. This finding could be related to two explanations: The rising and then constant relationship at lower to medium shares may be explained by the importance of a certain level of (intellectual) exchange among peers, e.g. similar workers, that is productivity enhancing, while the negative relationship at higher shares could be related to the decline of skill premia caused by an abundance of these skills in a particular firm. Third, we typically observe negative or at most U-shaped relationships between the regional shares of low-skilled and skilled workers and wages for both skilled and low-skilled individuals. This result would be in line with an explanation where an excess labor supply drives down wages and outweighs possible improvements in matching efficiency. Finally, this effect does not show up for the regional share of high-skilled workers, where we observe a unequivocally positive relationship with wages regardless of the individual skill level. This result is in line with both learning based explanations for human capital capital externalities as well as with Acemoglu's (1996) model of pecuniary externalities.

4 Econometric model

While the previous section provided first evidence on the existence of externalities of various types of human capital, there is no reason to assume that these simple descriptive results can be seen as causal relationships. High-productivity individuals may select into counties or firms with highly-educated peers which could create spurious correlations between regional or firm-level human capital and individual wages. Similarly, there are several county level characteristics, for instance the regional industry structure, that may very well be correlated with both regional human capital and individual wages. Phrased in terms of counterfactual reasoning, to identify the effect of regional or firm-level human capital on individual wages, we would like to compare the same individual observed in the same firm/industry in the same county in the same year with the same economic conditions but with different amounts of regional or firm-level human capital. While this is obviously impossible, I use a simple standard earnings equation with a more-way error-component structure augmented with measures of regional and firm-level human capital to control for possible observed and unobserved confounders and come close to this ideal. Specifically, the estimating equation can be written as

$$y_{ifjct} = \eta_i + \theta_c + \delta_t + \mu_j + \beta' X_{it} + \gamma' W_{ft} + \lambda' Z_{ct} + \tau_f * HC_{ft} + \tau_c * HC_{ct} + \epsilon_{it} \qquad (1)$$

where y_{ifjct} is the monthly log real wage of worker i in firm f in industry j situated in county c at time t. η_i, θ_c, δ_t and μ_j are individual, county, time and (1-digit)-industry specific fixed effects. HC_{ft} and HC_{ct} are the shares of low- and high-skilled workers at the firm and county level respectively with τ_f and τ_c being the parameters of interest. As the descriptive evidence in the previous section suggested possible non-linearities, both measures contain a second order polynomial. X_{it} contains time varying control variables on the person level, specifically age and age squared. W_{ft} contains time-varying variables on the firm-level, specifically firm size and the age structure of the plant's workforce measured by the shares of workers below 30, between 40 and 49 and with 50 and more years of age. Z_{ct} contains potential time-varying county-level confounders, specifically the regional unemployment rate and average sales in manufacturing per worker as proxies for regional economic conditions as well as the regional population to account for basic demographic changes. Finally, ϵ_{it} is a standard error term that is assumed to be uncorrelated with both HC_{ft} and HC_{ct} given the other variables and fixed effects.

The central identifying assumption in this setup is that ϵ_{it} is indeed uncorrelated with both HC_{ft} and HC_{ct} given the observed controls and the unobserved fixed effects. There are several potential threats to the validity of this assumption that have to be considered. First, there might be firm-specific unobserved heterogeneity that could be related to both firm-level human capital and individual wages. As the data is no true linked-employer-employee-dataset and does not contain firm identifiers, it is not possible to directly control for this heterogeneity. However, the data contains a variable that indicates whether an individual changed firms from one period to the other. Using this information, I re-estimate equation (1) using only individuals who stay in the same plant and the same county during the observation period. For these cases, individual, county and firm-specific fixed effects are empirically identical and controlled for by a standard fixed effects estimator. Additionally, this model allows for time-industry specific fixed effects and controls for the same time-varying confounders used in the base estimation.

Second, there might be concerns related to time-varying (observed and unobserved) confounders on the county level. The first is that the variables in Z_{ct} that are included to control for basic economic conditions on the county level may themselves be outcomes of regional human capital. If, for instance, the regional share of high-qualified workers influences regional unemployment and if regional unemployment influences wages, controlling for regional unemployment would eliminate this (indirect) wage effect of regional human capital. To allow for this possibility, I use a more parsimonious model without the regional control variables and with year-industry-specific fixed effects instead of δ_t and μ_j.

Another possible concern is the omission of important regional variables that influence both regional capital and wages. While the inclusion of the regional unemployment quota, the regional population and regional manufacturing sales control for some of the prime candidates for economic shocks that may influence both labor migration and regional wage levels, this concern remains valid. Unfortunately, the inclusion of time-county-fixed effects as an easy remedy is not possible as regional human capital varies only on a year-county-base which makes it multicollinear with county-specific trends. I also experimented with county-industry-year-specific fixed effects similar to Moretti (2004b). However, this approach turned out be computationally impossible even given the (rather large) resources of the research data center of the the Federal Employment Agency in the Institute of Employment Research.[4] Finally, I tried a (panel) instrumental variable approach similar to Moretti (2004c) where I instrumented firm-level and regional human capital with variables related to the regional supply of workers with various skill-levels in a fixed-effects regression on the sample of individuals without firm change. While the instruments, specifically the county-level numbers of school-dropouts, of graduates with a German *Abitur*, of students in vocational schools and of vocational schools, the *Bundesland* level shares of research and development expenditures in universities of GNP, of research and development personnel in universities of all workers and the percentage of university graduates in each age cohort (each as a second order polynomial), were shown to be valid, the estimates suffered from severe weak instrument problems rendering them uninformative.

Note that equation (1) does not contain measures of individual schooling. Given the individual fixed effects η_i, identification of the private returns to education would rely on individuals changing their educational status. However, as education in Germany typically takes place in the form of full-time education before entering the labor market as full-time regular employees, such simultaneous variation of wages and measures of education within

[4]In fact, estimation of these more-way error-component (or more-way fixed-effects) models is known to be computationally non trivial for datasets of the size used in this paper (see Andrews, Schank and Upward 2006). Estimation of the current model was possible using the Stata ado-file *felsdvreg* by Thomas Cornelissen (see Cornelissen 2006, 2008 for a description).

workers would likely be caused by special cases, e.g. individuals finishing evening schools. As the descriptive evidence in section 3 also suggests differences in the social returns to education for workers with different educational levels, I estimate equation (1) separately for low-skilled, skilled and high-skilled workers. Low-skilled workers are again those without post-school training, while skilled workers have completed vocational training and high-skilled workers are those with an academic degree. Equation (1) is estimated with both regional and firm-level human capital as well as separately with only one of the measures to gauge the importance of collinearity between firm-level and regional human capital for the results. As some of the variables of interest vary only on the county level, all standard errors are adjusted for clustering on the county level (see Moulton 1990).

5 Results

Consider the econometric results displayed in table 2. Columns (i), (ii) and (iii) are variations of the base estimates shown in equation (1) estimated with either firm-level or regional human capital or both, column (iv) gives the results of a model without regional control variables and industry-year-specific trends instead of the separate industry and time effects. Finally, the results in column (v) are obtained using the sample of individuals without firm change which implicitly controls for firm-specific unobserved heterogeneity. Before going into detailed comments, note that the results, in particular for the regional and firm-level shares of high-skilled workers, are very similar across models which mitigates the initial concerns about plant-specific unobserved heterogeneity and endogeneity. Note further, that – unsurprisingly given the relative size of the skill groups – the results for all workers without distinguishing between skill groups are generally similar to those for the skilled workers.

(Table 2 about here.)

To summarize the central results from table 2, we observe a remarkably similar and stable positive hump-shaped relationship between the firm-level share of high-skilled workers and the wages of low-skilled and skilled workers. This relationship is also found when controlling for firm-specific unobserved heterogeneity in column (v). For high-skilled workers, the point estimates suggest a similar pattern but are never significant. This result may – at least partially – be related to the higher level of censoring that affects the wages of this skill group. As we cannot expect the wage imputation to completely overcome this problem, somewhat smaller effects and less precise estimates may be expected for this group. In general, this result is perfectly in line with learning-based explanations of human capital externalities where lower-skilled individuals learn through interacting with higher skilled workers. Empirically, this result is qualitatively similar to the previous studies by Battu, Belfield and Sloane (2003), Martins and Jin (2008) and Mas and Moretti (2009).

Turning to the remaining estimates, another result that is relatively stable across skill groups and models is the non-existent relationship between individual wages and the regional share of high-skilled workers. Here, we observe a significant result only for the squared term and only when looking at skilled workers and dropping all regional control variables. These results do not support any of the theories that predict a link between regional high-skilled labor and individual wages, for instance theories of local learning or – through the fact that the wages of the high-skilled are also uninfluenced – matching based theories. Note, however, that the presence of county-specific fixed effects implies that identification of these education effects uses longitudinal variation within counties. As regions are relatively homogeneous over time, the within variation of regional human capital is very small which may be responsible for the lack of statistical significance.

For the regional and firm-level shares of low-skilled workers, the results are somewhat more inconclusive. Low-skilled and in particular skilled workers' wages seem to be negatively related to the (squared) firm-level shares of low-skilled workers. However, for the low-skilled this effect only appears when restricting the sample to individuals without firm change. For high-skilled workers we observe a positive relationship between individual wages and the firm-level shares of low-skilled workers. When restricting the sample to workers without a firm change, we additionally see evidence for a non-linear (u-shaped) relationship. There is unfortunately no previous empirical evidence or theoretical explanation that would help to put these findings into perspective. The results are similarly inconclusive for the regional shares of low-skilled workers. Here, we observe a u-shaped relationship for low-skilled and skilled workers when restricting the sample to workers without a firm change. Similar, though insignificant results are also found when dropping all regional controls. For the base estimates and high-skilled workers in general, there does not seem to be a stable relationship between the regional shares of low-skilled workers and individual wages. Unfortunately, there is again no previous evidence that could help to explain these results.

To help the interpretation of the results, figures 5 and 6 present simulated wage increases for changes in the regional and firm-level shares of the respective education group using the results for the stayer sample from column (v) of table 2. Remember that these are the results that are least likely to suffer from biases related to unobserved heterogeneity. Simulations based on the results from the base model in column (i) are very similar and can be found in the appendix. The range of values that is considered in the simulations has been restricted to lie between the respective sample minima and maxima to avoid out-of-sample predictions. Remember from the density estimates in figure 1 that the distributions of the firm-level shares of low- and high-skilled workers are both right-skewed with most individuals being in firms with less than 40% low-skilled and less than 20% high-skilled workers. On a regional level, most individuals work in regions with between 10% and 25% low-skilled and between 3% and 15% high-skilled workers.

(Figures 5 and 6 about here.)

Starting with figure 5 and the firm-level shares of low-skilled workers, we notice that wage effects are typically very small over the empirically relevant shares from 0% to 40%. For low-skilled and skilled workers, we observe wage drops of less than 2% when increasing the firm-level shares from 0% to 40%. For high-skilled workers, we observe corresponding wage increases by less than 1%. For the regional shares of low-skilled workers, we observe rather large wage penalties between 2% and 4% for low-skilled workers. Note that these penalties are declining with an increasing regional employment of low-skilled workers. If one sees the local share of low-skilled workers as an indicator for the regional number of jobs for low-skilled workers, this decline would be broadly in line with supply and demand-based explanations. For skilled workers, we observe smaller wage penalties of 1% to 2% that are also declining with an increasing regional share of low-skilled workers. For high-skilled workers, the simulations suggest rather large wage premia of 3.5% to 4%. However, as the (positive) linear term is not and the (negative) quadratic term is only borderline significant, it seems sensible not to put too much weight on this result.

Consider now the simulated wage increases related to the firm-level and regional shares of high-skilled workers that are displayed in figure 6. For low-skilled and skilled workers, the results suggest relative similar wage effects between slightly above 0% to 3% for the empirical relevant firm-level shares between 0% and 20%. For high-skilled workers the simulations suggest much higher effects in the magnitude of up to 10%. However, the underlying coefficients are not significant on conventional levels. Note that these effects, although they are not directly comparable due to different definitions of human capital, seem somewhat smaller than those found by Battu, Belfield and Sloane (2003) and Martin and Jin (2008). A possible explanation for this divergence of results is the fact that Battu, Belfield and Sloane (2003) cannot control for firm- and individual-specific fixed effects, while Martins and Jin (2008) who conduct a firm-level analysis cannot control for unobserved heterogenity of individuals. For the regional shares of high-skilled workers, the results suggest relative minor wage effects for skilled and high-skilled workers. For low-skilled workers, the simulations suggest rather large wage penalties associated with higher regional shares of high-skilled workers. However, as the regional effects are again based on insignificant coefficients, none of them should be taken too seriously.

To sum up, the results of this paper suggest significant positive effects of the firm-level share of high-skilled workers on the wages of low-skilled and skilled workers but not on the wages of high-skilled workers. This finding is in line with learning based theories of human capital externalities, at least if one is willing to assume that learning-spillovers are more likely from higher to lower educated workers. However, the wage increases caused by variation in the firm-level share of high-skilled workers are often relatively small over empirically relevant shares. In some estimations I also find negative wage effects for the regional shares of low-skilled workers. No such effects are found for the firm-level shares of low-skilled workers and the regional shares of high-skilled workers. While the lack of significance of the results for regional human capital may be related to the relatively small longitudinal variation within regions, the estimated effects are also often small in economic terms. Overall, the results suggest that learning-spillovers from high- to low-skilled workers might matter on the firm level, while no support is found for the existence of social returns to education on the regional level.

6 Conclusion

This paper provided evidence on the anatomy of human capital externalities arising from both firm-level and regional human capital. Using panel data from German social security records at the individual, firm and regional level, I estimated earnings functions augmented with measures of firm-level and regional human capital while controlling for various types of unobserved heterogeneity. The results show robust support for the existence of social returns to the firm-level share of high-skilled workers for low-skilled and skilled workers. No such effects exist for high-skilled workers. This finding is in line with the existence of learning spillovers from higher to lower qualified workers within firms. However, the wage effects are often quite small over empirically relevant shares. No effects are found for the firm-level shares of low-skilled workers and the regional shares of high-skilled workers. For the regional share of low-skilled workers, the evidence is more inconclusive with negative effects being found in some estimations. While the lack of significance of the results for regional human capital might be explained by the relatively small longitudinal variation of human capital within regions, the estimated effects are also often small in economic terms.

Taken together, the results are in line with learning spillovers at the firm level. However, they provide relatively few support for either theories of regional learning spillovers or matching based explanations of human capital externalities.

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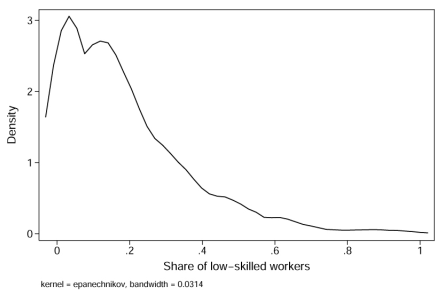
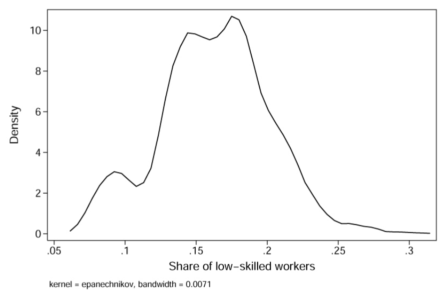
8 Tables and figures

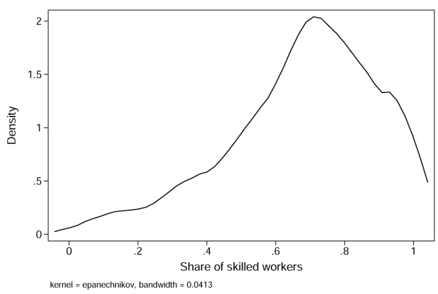
Figure 1: Observed distributions of regional and firm-level human capital variables, Kernel-density estimates



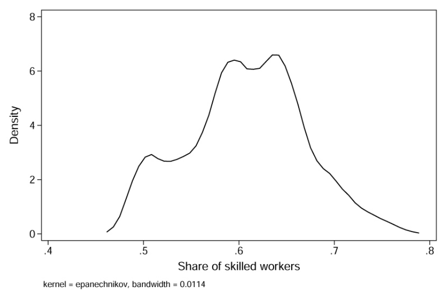
(a) Firm-level share of low-skilled workers



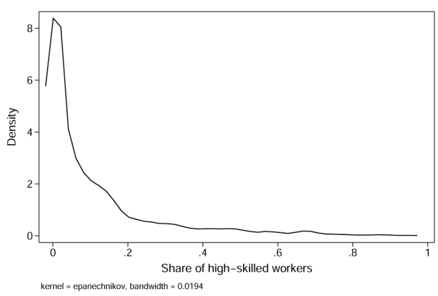
(b) Regional share of low-skilled workers



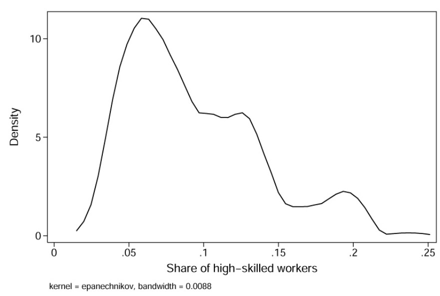
(c) Firm-level share of skilled workers



(d) Regional share of skilled workers



(e) Firm-level share of high-skilled workers



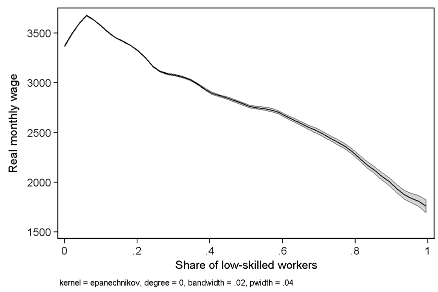
(f) Regional share of high-skilled workers

Note: Kernel density estimates using epanechikov-kernel.

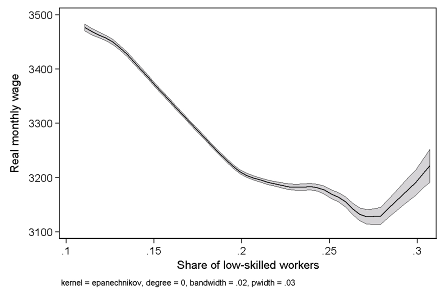
Table 1: DESCRIPTIVE STATISTICS, ALL YEARS

Variable	Mean	Standard deviation overall	Standard deviation within	Min.	Max.
Real monthly wage (€, 2000 prices)	3,301.73	1,082.27	185.82	805.12	5,190.92
Log monthly wage	8.05	.3443	.0632	6.69	8.55
Age	41.78	8.83	1.0449	25	60
Firm size (number of employees)	1,362.91	4,442.72	589.95	3	42,882
Share of workers below 30 years of age	.1929	.1214	.0387	0	1
Share of workers between 30 and 39 years of age	.2715	.0984	.0400	0	1
Share of workers between 49 and 49 years of age	.2991	.0944	.0378	0	1
Share of workers above 50 years of age	.2365	.1149	.0363	0	1
Share of low-skilled workers (firm)	.1988	.1616	.0423	0	.9947
Share of skilled workers (firm)	.6677	.1855	.0467	0	.9995
Share of high-skilled workers (firm)	.1115	.1586	.0316	0	.9974
Share of low-skilled workers (region)	.1752	.0314	.0075	.1107	.3073
Share of skilled workers (region)	.6031	.0522	.0089	.4731	.7263
Share of high-skilled workers (region)	.0908	.0443	.0079	.0238	.2403
Regional unemployment quota	9.17	2.99	.9230	3.4	23.7
Regional manufacturing sales per head (1000 €)	256.36	135.68	42.01	65.24	1,376.25
Regional population	388,253.5	363,493.1	63,809.48	35,058	1,748,544
No. of Obs.			583,078		
No. of Individuals			179,501		

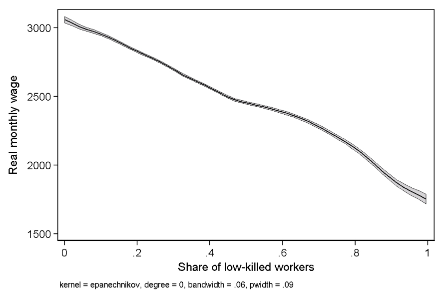
Figure 2: Non-parametric regression estimates: Real monthly wages and firm-level or regional shares of low-skilled workers



(a) Firm-level share of low-skilled workers and general wages

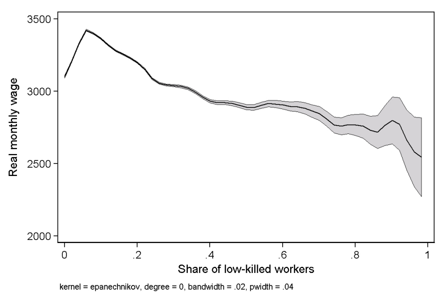


(b) Regional share of low-skilled workers and general wages



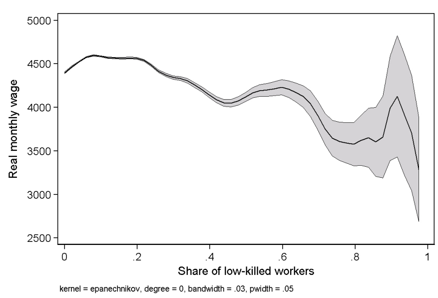
(c) Firm-level share of low-skilled workers and wages of the low-skilled

(d) Regional share of low-skilled workers and wages of the low-skilled



(e) Firm-level share of low-skilled workers and wages of the skilled

(f) Regional share of low-skilled workers and wages of the skilled



(g) Firm-level share of low-skilled workers and wages of the high-skilled

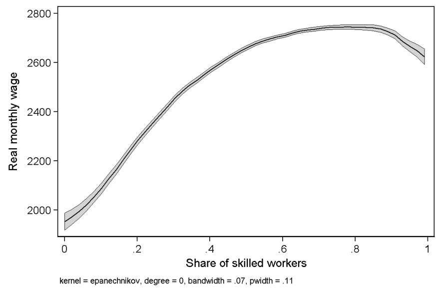
(h) Regional share of low-skilled workers and wages of the high-skilled

Note: Local polynomial smoothing, 95% confidence bounds in grey.

Figure 3: Non-parametric regression estimates: Real monthly wages and firm-level or regional shares of skilled workers

(a) Firm-level share of skilled workers and general wages

(b) Regional share of skilled workers and general wages



(c) Firm-level share of skilled workers and wages of the low-skilled

(d) Regional share of skilled workers and wages of the low-skilled

(e) Firm-level share of skilled workers and wages of the skilled

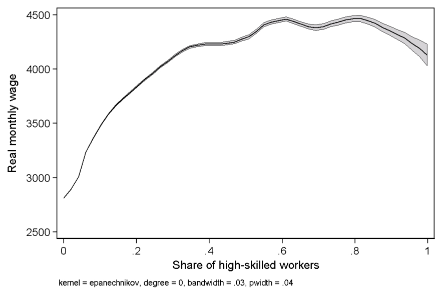
(f) Regional share of skilled workers and wages of the skilled

(g) Firm-level share of skilled workers and wages of the high-skilled

(h) Regional share of skilled workers and wages of the high-skilled

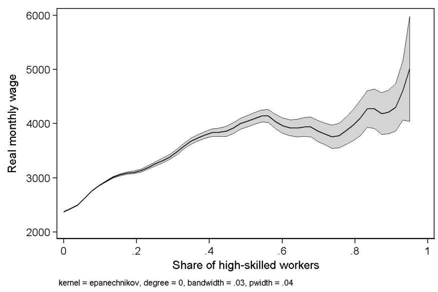
Note: Local polynomial smoothing, 95% confidence bounds in grey.

Figure 4: Non-parametric regression estimates: Real monthly wages and firm-level or regional shares of high-skilled workers

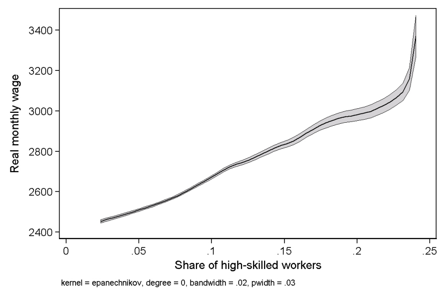


(a) Firm-level share of high-skilled workers and general wages

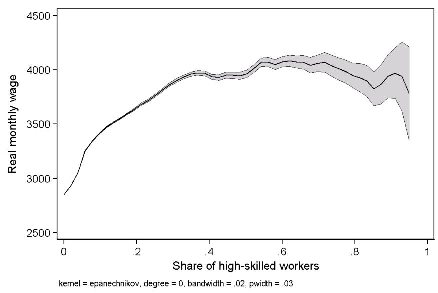
(b) Regional share of high-skilled workers and general wages



(c) Firm-level share of high-skilled workers and wages of the low-skilled

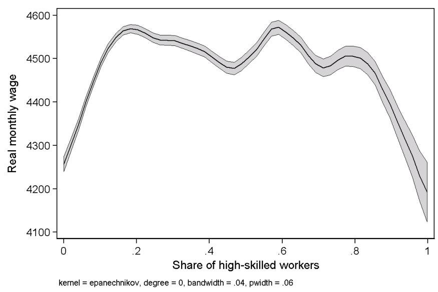


(d) Regional share of high-skilled workers and wages of the low-skilled

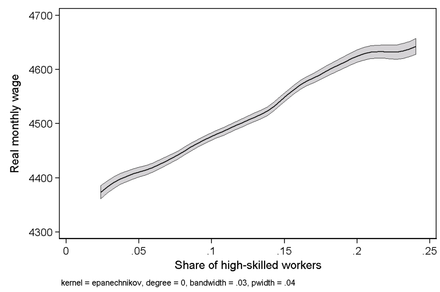


(e) Firm-level share of high-skilled workers and wages of the skilled

(f) Regional share of high-skilled workers and wages of the skilled



(g) Firm-level share of high-skilled workers and wages of the high-skilled



(h) Regional share of high-skilled workers and wages of the high-skilled

Note: Local polynomial smoothing, 95% confidence bounds in grey.

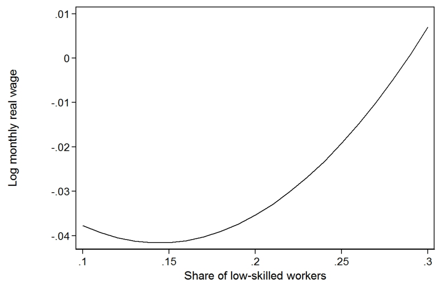
Table 2: Fixed-effects-regression results, parameters of interest, West-German men, dependent variable: log real monthly wages (€, in 2000 prices)

Variable	Base estimates (i)	(ii)	(iii)	No regional controls (iv)	Individuals without firm change (v)
All individuals					
Firm: Share of low-skilled workers	.0350*	(–)	.0355**	.0387**	.0392***
	(.0179)		(.0181)	(.0171)	(.0106)
Firm: Share of low-skilled workers	-.1410***	(–)	-.1407***	-.1437***	-.1474***
(squared)	(.0297)		(.0297)	(.0288)	(.0188)
Firm: Share of high-skilled workers	.2049***	(–)	.2050***	.2010***	.1852***
	(.0175)		(.0176)	(.0173)	(.0150)
Firm: Share of high-skilled workers	-.1806***	(–)	-.1800***	-.1769***	-.1651***
(squared)	(.0227)		(.0227)	(.0226)	(.0213)
Region: Share of low-skilled workers	.0283	.0334	(–)	-.4585	-.5771***
	(.4154)	(.4125)		(.4411)	(.1480)
Region: Share of low-skilled workers	.4921	.3908	(–)	1.8736*	2.0014***
(squared)	(.9560)	(.9534)		(1.0510)	(.3528)
Region: Share of high-skilled workers	.0480	.0498	(–)	-.2500	-.1469
	(.3774)	(.3807)		(.3931)	(.1198)
Region: Share of high-skilled workers	1.1243	1.1649	(–)	2.0522	.6887
(squared)	(1.4705)	(1.5037)		(1.5929)	(.4501)
No. of Obs.		583,078			547,347
No. of Indiv.		179,501			166,737
Low-skilled individuals					
Firm: Share of low-skilled workers	-.0306	(–)	-.0302	-.0256	-.0079
	(.0416)		(.0416)	(.0415)	(.0338)
Firm: Share of low-skilled workers	-.0291	(–)	. -.0292	-.0325	-.0700*
(squared)	(.0465)		(.0465)	(.0467)	(.0384)
Firm: Share of high-skilled workers	.2345***	(–)	2329***	.2284**	.1910***
	(.0627)		(.0627)	(.0630)	(.0495)
Firm: Share of high-skilled workers	-.1903*	(–)	-.1852*	-.1819*	-.1726*
(squared)	(.1071)		(.1081)	(.1083)	(.1001)
Region: Share of low-skilled workers	-.0185	-.0697	(–)	-.8683	-.7679**
	(.5242)	(.5208)		(.6015)	(.3751)
Region: Share of low-skilled workers	.6005	.6471	(–)	2.8776*	2.9332***
(squared)	(1.1920)	(1.1895)		(1.5351)	(.8638)
Region: Share of high-skilled workers	-.4111	-.4659	(–)	-.8364	-.5928
	(.8400)	(.8391)		(.8062)	(.3985)
Region: Share of high-skilled workers	1.3567	1.5803	(–)	3.2600	1.5994
(squared)	(2.7194)	(2.6980)		(2.6421)	(1.4691)
No. of Obs.		76,704			72,418
No. of Indiv.		26,219			24,115
Skilled individuals					
Firm: Share of low-skilled workers	.0035	(–)	.0036	.0093	.0063
	(.0201)		(.0202)	(.0189)	(.0120)
Firm: Share of low-skilled workers	-.0724**	(–)	-.0718**	-.0771**	-.0721***
(squared)	(.0327)		(.0329)	(.0315)	(.0226)
Firm: Share of high-skilled workers	.2075***	(–)	.2074***	.2004***	.1738***
	(.0222)		(.0223)	(.0214)	(.0177)
Firm: Share of high-skilled workers	-.1904***	(–)	-.1889***	-.1840***	-.1283***
(squared)	(.0363)		(.0363)	(.0352)	(.0296)
Region: Share of low-skilled workers	.1001	.0868	(–)	-.3149	-.3345*
	(.4217)	(.4232)		(.4327)	(.1796)
Region: Share of low-skilled workers	.1521	.1199	(–)	1.3851	1.3197***
(squared)	(.9362)	(.9516)		(.9836)	(.4196)
Region: Share of high-skilled workers	-.0424	-.0413	(–)	-.3318	-.0926
	(.3636)	(.3654)		(.3962)	(.1498)
Region: Share of high-skilled workers	1.7490	1.8283	(–)	2.7472*	.8697
(squared)	(1.5134)	(1.5662)		(1.6357)	(.5888)
No. of Obs.		422,882			398,670
No. of Indiv.		130,920			121,939
High-skilled individuals					
Firm: Share of low-skilled workers	.0688**	(–)	.0683**	.0689**	.0519*
	(.0342)		(.0343)	(.0345)	(.0311)
Firm: Share of low-skilled workers	-.1145	(–)	-.1147	-.1128	-.1128*
(squared)	(.0714)		(.0715)	(.0719)	(.0639)
Firm: Share of high-skilled workers	.0581	(–)	.0581	.0613	.0403
	(.0375)		(.0375)	(.0376)	(.0332)
Firm: Share of high-skilled workers	-.0667	(–)	-.0671	-.0695	-.0541
(squared)	(.0463)		(.0464)	(.0466)	(.0379)
Region: Share of low-skilled workers	.3280	.3281	(–)	.3842	.4817
	(.5296)	(.5286)		(.5056)	(.3374)
Region: Share of low-skilled workers	-.6671	-.6587	(–)	-.8269	-1.4069*
(squared)	(1.3564)	(1.3676)		(1.3439)	(.8482)
Region: Share of high-skilled workers	.3301	.3551	(–)	.2733	.1847
	(.5363)	(.5416)		(.4630)	(.2339)
Region: Share of high-skilled workers	-2.3423	-2.4122	(–)	-2.0914	-1.2309
(squared)	(1.5247)	(1.5381)		(1.3230)	(.7853)
No. of Obs.		83,492			76,259
No. of Indiv.		26,696			23,995

Coefficients, standard errors adjusted for clustering at the county level in parentheses. ***/**/* denote significance on the 1%, 5% and 10% level respectively. Columns (i), (ii) and (iii) include individual, regional (county) and year-specific fixed effects, 1-digit industries, age and age-squared, firm size measured by the number of employees, the shares of workers below 30, between 40 and 50 and above 50 years of age, the regional unemployment quota, regional manufacturing sales per head and the regional population. Columns (iv) and (v) contain individual, regional and industry-year fixed effects. Column (iv) excludes the regional unemployment quota, regional manufacturing sales per head and the regional population. The estimates in column (v) also control for firm-specific unobserved heterogeneity.

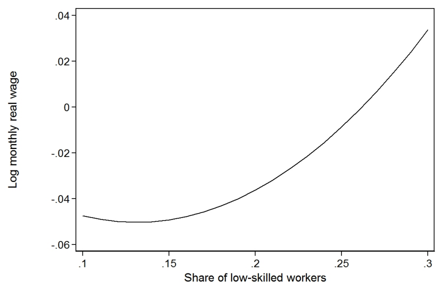
Figure 5: Simulated wage changes by firm-level and regional shares of low-skilled workers, individuals without firm change

(a) Firm-level share of low-skilled workers and general wages



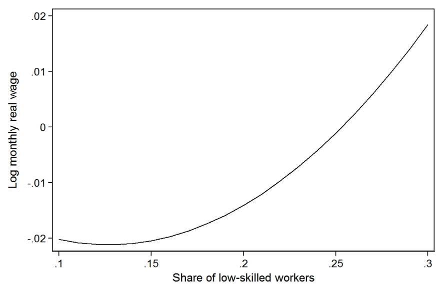
(b) Regional share of low-skilled workers and general wages

(c) Firm-level share of low-skilled workers and wages of the low-skilled

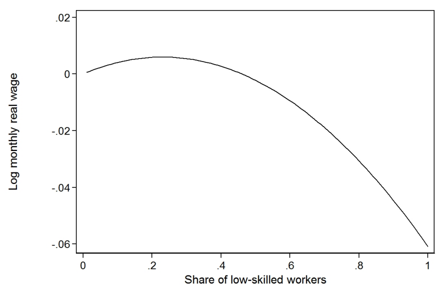


(d) Regional share of low-skilled workers and wages of the low-skilled

(e) Firm-level share of low-skilled workers and wages of the skilled



(f) Regional share of low-skilled workers and wages of the skilled

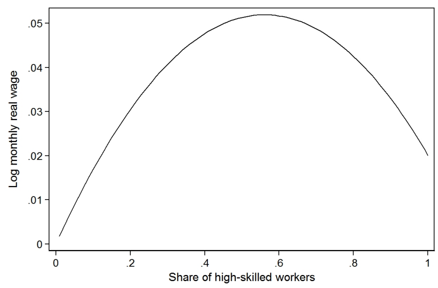


(g) Firm-level share of low-skilled workers and wages of the high-skilled

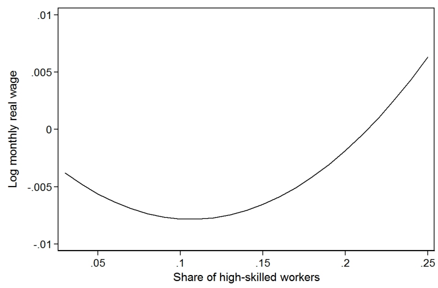
(h) Regional share of low-skilled workers and wages of the high-skilled

Note: Simulations are based on the coefficients from column (v) of table 2. The range of the simulations has been restricted to values between the sample minimum and maximum to avoid out-of-sample predictions.

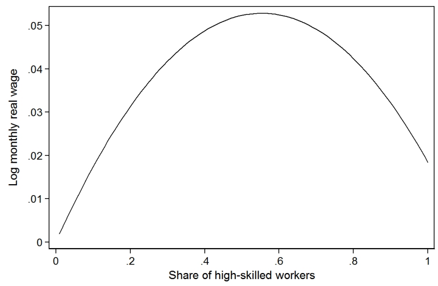
Figure 6: Simulated wage changes by firm-level and regional shares of high-skilled workers, individuals without firm change



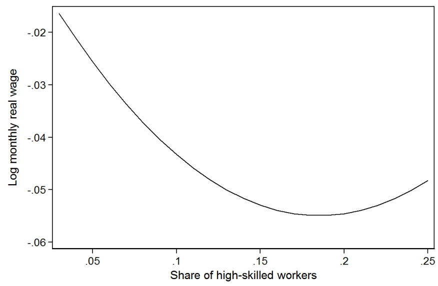
(a) Firm-level share of high-skilled workers and general wages



(b) Regional share of high-skilled workers and general wages

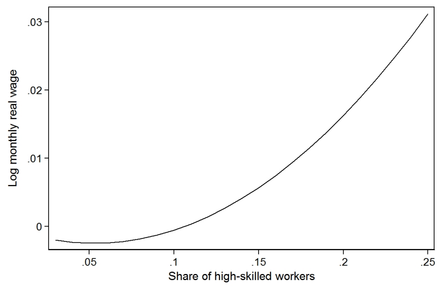


(c) Firm-level share of high-skilled workers and wages of the high-skilled

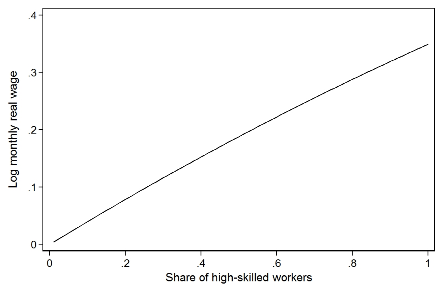


(d) Regional share of high-skilled workers and wages of the high-skilled

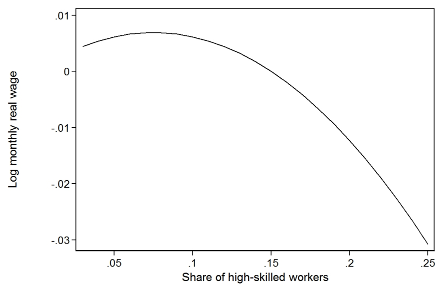
(e) Firm-level share of high-skilled workers and wages of the skilled



(f) Regional share of high-skilled workers and wages of the skilled



(g) Firm-level share of high-skilled workers and wages of the high-skilled



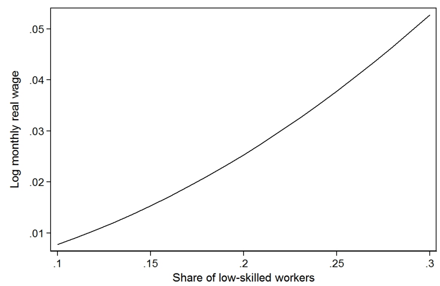
(h) Regional share of high-skilled workers and wages of the high-skilled

Note: Simulations are based on the coefficients from column (v) of table 2. The range of the simulations has been restricted to values between the sample minimum and maximum to avoid out-of-sample predictions.

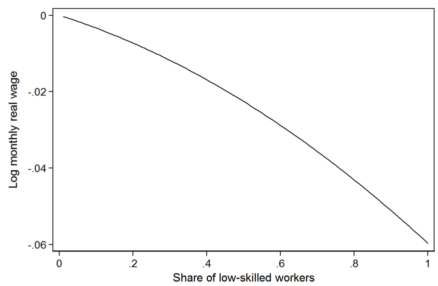
9 Appendix: Additional figures

Figure 7: Simulated wage changes by firm-level and regional shares of low-skilled workers, base estimates

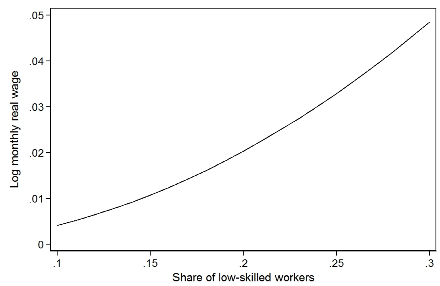
(a) Firm-level share of low-skilled workers and general wages



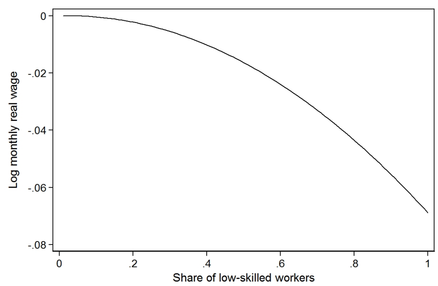
(b) Regional share of low-skilled workers and general wages



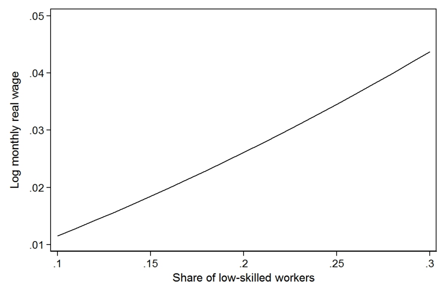
(c) Firm-level share of low-skilled workers and wages of the low-skilled



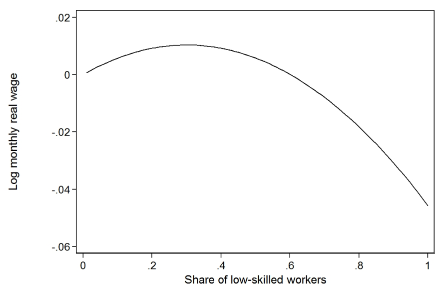
(d) Regional share of low-skilled workers and wages of the low-skilled



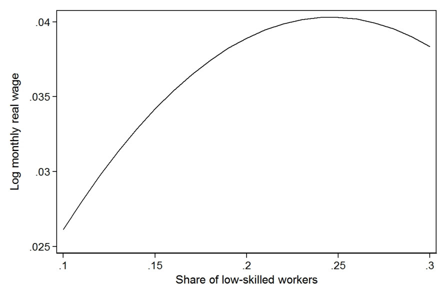
(e) Firm-level share of low-skilled workers and wages of the skilled



(f) Regional share of low-skilled workers and wages of the skilled



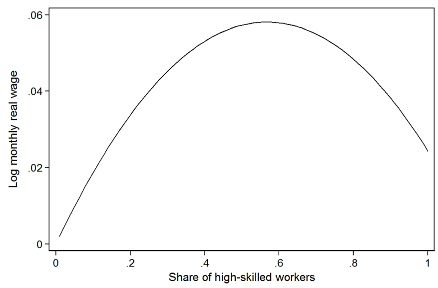
(g) Firm-level share of low-skilled workers and wages of the high-skilled



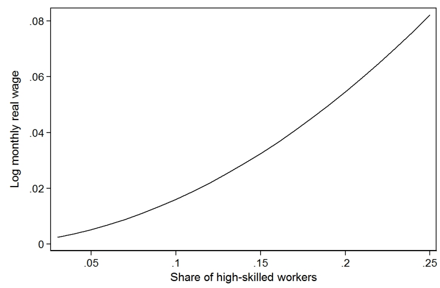
(h) Regional share of low-skilled workers and wages of the high-skilled

Note: Simulations are based on the coefficients from column (i) of table 2. The range of the simulations has been restricted to values between the sample minimum and maximum to avoid out-of-sample predictions.

Figure 8: Simulated wage changes by firm-level and regional shares of high-skilled workers, base estimates

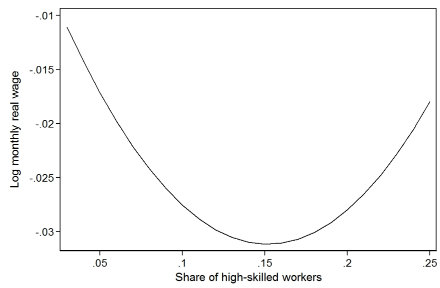


(a) Firm-level share of high-skilled workers and general wages

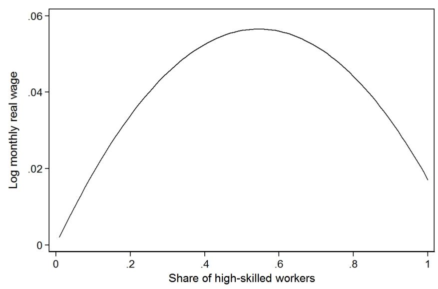


(b) Regional share of high-skilled workers and general wages

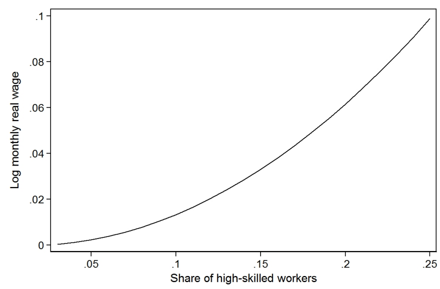
(c) Firm-level share of high-skilled workers and wages of the high-skilled



(d) Regional share of high-skilled workers and wages of the high-skilled

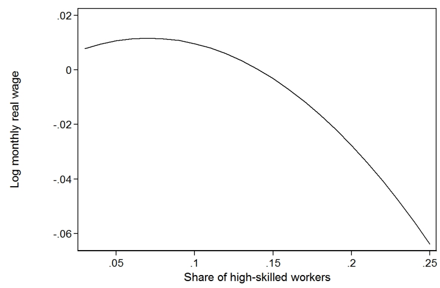


(e) Firm-level share of high-skilled workers and wages of the skilled



(f) Regional share of high-skilled workers and wages of the skilled

(g) Firm-level share of high-skilled workers and wages of the high-skilled



(h) Regional share of high-skilled workers and wages of the high-skilled

Note: Simulations are based on the coefficients from column (i) of table 2. The range of the simulations has been restricted to values between the sample minimum and maximum to avoid out-of-sample predictions.

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