Decomposing Within-Firm Wage Inequality

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Abstract

Using matched employer-employee data from Germany, we show that wage differences among employees who perform similar tasks (horizontal wage inequality, HWI) and employees who perform different tasks (vertical wage inequality, VWI) contribute equally to the overall wage inequality within firms. While VWI can be almost exclusively explained by the remuneration for employee characteristics (e.g., ability or education), these employee heterogeneities explain only about three-quarters in HWI. The remaining unexplained quarter is positively correlated with the existence of profit sharing programs, written employee assessments, written employee targets, firm profitability, and monitoring costs measured by the task complexity of an occupation and the size of an establishment or firm. These findings suggests that pay-for-performance schemes are a plausible explanation for the quarter of HWI that is not related to employee characteristics.

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1. Introduction

Wage differences within firms contribute substantially to the inequality of wages in the economy (Song et al., 2019). Surprisingly, however, only little is known about its key components. One reason for this is that the empirical investigation requires detailed information about what wages the firms pay to their individual workers.

In this paper, we use administrative matched employer-employee data to decompose wage differences within firms into wage inequality among employees who perform different tasks ("vertical wage inequality", henceforth VWI) and inequality among employees with similar tasks ("horizontal wage inequality", HWI). Subsequently, we split HWI and VWI into inequality that is due to the remuneration of heterogeneous employee characteristics and residual inequality. This decomposition, plus our analysis on what explains residual inequality, will help to better understand the origins of within-firm wage inequality.

Our dataset links employee-level information from the German social security system with firm-level data from Bureau van Dijk's Orbis database. It covers 16,630,960 employees, 205,858 establishments, and 87,440 firms between 2010 and 2016. We measure HWI as the variance of employees' log wages in the same occupation-task group and VWI as the variance of their log wages across different occupation-task groups. We differentiate between 144 occupational groups and up to four different task levels within these groups, which results in 431 occupation-task groups.[1] To make sure that unobserved heterogeneity across establishments within firms does not bias the results, we conduct most of our analysis on the establishment-level.

Our first result is that HWI and VWI contribute approximately equally to the overall variation of wages within establishments. Specifically, HWI accounts for 49.2 percent of the wage variation, and VWI for 50.8 percent. To check whether task heterogeneity within occupation-task groups has a substantial impact on this result, we repeat the analysis using information on occupational subgroups. This finer classification allows us to distinguish 1,286

[1] We rely on the KldB2010 occupations classification scheme. Examples for occupational groups are "241: occupations in metal-making", "242: occupations in metalworking" and "243: occupations in treatment of metal surfaces", and the task levels are "unskilled/semiskilled tasks", "skilled tasks", "complex tasks", and "highly complex tasks". Appendix A.1 provides a more comprehensive description of the classification scheme, and Appendix A.2 lists all occupation-task groups.

unique suboccupation-task groups among which tasks are more homogeneous.[2] Our results reveal that the relevance of HWI decreases only slightly from 49.2 percent for our baseline measure to 46.6 percent. Thus, we conclude that although task heterogeneity plays some role, it is unlikely to lead to a substantial over-estimation of HWI.

Next, we want to understand the role of heterogeneous employee characteristics for HWI and VWI. To this end, we use a wage model in the spirit of Abowd, Kramarz and Margolis (1999) (henceforth AKM) to decompose HWI and VWI into a part that is related to heterogeneous employee characteristics and a residual part.[3] In this model, the wage is explained by observable employee characteristics, such as age and education, and unobservable, permanent employee and establishment characteristics, which are measured by fixed effects.[4] We find that that the remuneration for heterogeneous employee characteristics accounts for 95 percent of VWI—a result which is consistent with previous literature. Mueller, Ouimet and Simintzi (2017b) document that wage differences across hierarchy levels are associated with larger firms and higher firm performance and explain this result by means of differences in managerial talent. Heterogeneity in employee characteristics also account for a substantial part of about two-quarters in the HWI, leaving the remaining quarter unexplained.

Since residual HWI is an important component of wage inequality, we aim at explaining those wage differences among employees with similar characteristics who perform similar task. Conceptually, pay-for-performance schemes that adjust employees' wages for their performance could provide an explana-

[2]An example for a suboccupation-task group is "24232: Occupations in metalworking: cutting—skilled tasks", which corresponds to "242-2: Occupations in metalworking—skilled tasks" in our baseline classification. See Appendix A.1 for more details.

[3]Our implementation of the AKM model that is similar to Card, Heining and Kline (2013) (henceforth CHK). The AKM model is widely used in labor economics (e.g., CHK; Card et al., 2018; Song et al., 2019) and, more recently, in financial economics (e.g., Matveyev, 2017; Babina et al., 2019; He and le Maire, 2019). We are aware that there is a discussion about the vulnerability of the AKM model to limited mobility bias. We discuss this issue in the context of this paper in Section 3.4.1.

[4]Establishment fixed effects also control for differences across firms related to size, ownership structures, unionization rates, and many other factors that might affect wage levels (Bloom et al., 2018; Ellul, Pagano and Schivardi, 2018; Bradley, Kim and Tian, 2017; Lee and Mas, 2012), if these factors are constant during our sample period. Since we only consider German firms in our sample, national regulations that affect all firms at the same time, such as employment programs (e.g., Agarwal et al., 2021), do not affect our results.

tion. Examples of those schemes include bonus payments, piece rates, but also base pay adjustments due to past or expected productivity (Lazear, 2018).[5] The existence of those schemes creates dispersed wages within occupations due to performance differences across employees and over time (Seiler, 1984; Lemieux, MacLeod and Parent, 2009).

To understand the role of pay-for-performance schemes for residual HWI, we assess its relationship with several firm or establishment characteristics. We start by analyzing the relationship between residual HWI and a survey-based measure for the existence of profit sharing programs on the establishment level, which is available for a smaller sample. If pay-for-performance schemes play an important role for residual HWI, we would expect to find a (strong) positive correlation with the existence of profit sharing programs in an establishment. We find that residual HWI increases by 12.3 percent, relative to its mean, for a hypothetical establishment that changes the share of employees participating in a profit-sharing program from zero to one. Furthermore, we find some evidence that survey-based measures for the existence of written employee assessments and written employee targets, which are important ingredients of profit sharing programs that reward individual employees based on their performance, are positively correlated with residual HWI.

The implied mechanism through which profit sharing affects residual HWI might be firm profitability: if firms are more profitable, they share more of the profits with their productive employees, leading to more residual HWI. To test this mechanism, we link residual HWI to measures for firm performance. We find a positive correlation between residual HWI and EBITDA, EBIT, net income, and cash flow, all scaled by total assets. This result indicates that wages among employees who perform similar tasks and have similar characteristics are more unequal if firms are profitable, which is in line with a pay-for-performance based explanation of residual HWI.

After that, we exploit that pay-for-performance schemes are conceptually linked to monitoring costs. Firms can use pay-for-performance schemes to re-

[5]Expected productivity of employees can differ across firms and over time because of idiosyncratic match effects between employees and employers. Those match effects occur, for example, due to complementarities between employees and firms or drifts in the portable component of employees' earnings power (see CHK for a detailed discussion). He, Kennes and le Maire (2018) provide a general framework for the specification of production complementarities between workers and firms.

duce their agency conflicts with employees (Ross, 1973), which is especially important when monitoring is costly because employees' actions are difficult to observe or because of uncertainty about their optimal actions (Holmstrom, 1979; Prendergast, 2002). We approximate uncertainty about optimal actions by considering the task complexity of a fine-grained occupation. For this purpose, we rely on the classification scheme of Autor, Levy and Murnane (2003) and the occupational complexity according to our occupational classification scheme.

Sorting occupations according to their residual HWI reveals that it is higher in occupations with high task complexity and more analytical and interactive tasks that do not follow a routine (e.g., engineering and science), while it is lower in occupations with mainly manual tasks (e.g., cleaning and vehicle driving).[6] Regressions show that a one-standard-deviation increase in the fraction of analytical nonroutine tasks is associated with a 19.7% higher residual HWI, and the corresponding values for interactive nonroutine tasks and occupational complexity are 10.1% and 17.1%, respectively.

When we use firm size as a proxy for uncertainty about employees' actions (Garen, 1985), a graphical analysis reveals that residual HWI increases monotonically with size and more than doubles when comparing the smallest firm decile to the largest. Regression models show that residual HWI is about 12.5% higher, relative to its mean, for a firm that has twice as many employees. To mitigate concerns about unobservable firm heterogeneity, we alternatively focus on multi-establishment firms and show that the same patterns exist when we add firm times year fixed effects and compare the size and task complexity of different establishments within the same firms.

Taken together, we find that residual HWI is positively correlated with the existence of profit sharing programs, written employee assessments, written employee targets, firm profitability, and monitoring costs measured by task complexity of an occupation and the size of an establishment or firm. Although none of these results is conclusive by itself, taken together they suggest that pay-for-performance schemes are plausible explanations of residual HWI.

Our paper contributes to the literature on within-firm wage inequality.

[6] Among the largest 50 occupations, the five with the highest residual HWI are classified as highly complex with analytical, nonroutine tasks. The bottom five occupations are classified as less complex with manual tasks (four with routine, one with nonroutine tasks).

Studies that focus on overall within-firm wage inequality include, for instance, Martins (2008), Barth et al. (2012), and Gartenberg and Wulf (2020). Song et al. (2019) document the importance of overall wage differences within firms for the overall wage inequality in the economy, and Tang, Tang and Wang (2020) show that the majority of the increase in wage inequality in the previous decades occurred within occupations. van der Velde (2020) focuses on wage inequality within occupations and finds that the variance of wages is higher in occupations where tasks complement newer technologies. Mueller, Ouimet and Simintzi (2017a) and Mueller, Ouimet and Simintzi (2017b) measure within-firm wage inequality as pay differences between hierarchy levels of a firm, which corresponds to what we call VWI. They show that firm growth leads to more within-firm pay inequality and that pay inequality is associated with higher valuations and stronger operating performance. We complement this literature by providing a comprehensive decomposition of within-firm wage inequality into VWI due to employee heterogeneity (48.3 percent), HWI due to employee heterogeneity (37.3 percent), residual HWI (11.9 percent), and residual VWI (2.5 percent).

Our paper is also related to the literature that focuses on incentive pay for employees. While generally accepted proxies for incentive-provision to top management have been developed and frequently explored in the financial economics literature,[7] empirical assessments of performance-based pay in the context of employees is difficult (Prendergast, 1999). Despite theoretical models that lead to conflicting empirical predictions (Akerlof and Yellen, 1990; Manso, 2011; Hellmann and Thiele, 2011), the empirical literature is scarce and mostly relies on survey-based measures for small samples, often single firms (Gibbons, 1998; Lazear, 2018), or well-controlled experiments (Breza, Kaur and Shamdasani, 2018). Our findings suggest that a substantial part of HWI is related to incentive provision to employees via pay-for-performance schemes. Thus, residual HWI could be an interesting empirical proxy for incentive pay and pay-for-performance schemes that is available for a large number of firms.

[7] Examples of studies that analyze the incentive pay of CEOs or other top managers are Jensen and Murphy (1990) and Aggarwal and Samwick (2003). Murphy (2013) and Edmans, Gabaix and Jenter (2017) provide an overview of the executive compensation literature.

2. Sample and data

The core of our dataset is the employee history file (Beschäftigten-Historik, BeH), which is provided by the Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung, IAB). This matched employee-employer data originates from earnings records of the German social security system and includes person-level information on total earnings, occupation, days worked, education, and part-time or full-time status.[8]

We identify the main employment period held by each full-time employee in a given year, that is, the employment spell with the highest total wage sum (including bonus payments) in that year. Similar to CHK and Bellmann et al. (2020), we only include full-time jobs (excluding marginal employment and apprenticeship) held by employees aged 20 to 60 from 2010 to 2017. We then calculate the average daily wage by dividing the total earnings by the total duration of the main employment spell.[9]

The employers allocate occupation codes to each of their employees in each employment spell according to the KldB2010 occupational classification scheme (please refer to Appendix A.1 for a detailed description). We use the first three digits of this classification scheme, which distinguish 144 different occupational groups in our sample, plus the fifth digit, which distinguishes up to four task complexity levels within occupational groups. Because not all complexity levels exist for all occupations, our final dataset includes 431 unique occupation-task groups according to this three-plus-fifth-digit KldB2010 classification (the full list is shown in Appendix A.2).[10]

The BeH provides information on employees and establishments but not on

[8]Since the data originates from the social security system, it does not include information about civil servants or self-employed persons. For further details on the dataset, please refer to the technical report by Antoni, Ganzer and vom Berge (2016).

[9]Wages in the BeH are censored at a time- and region-specific threshold, the so-called contribution assessment ceiling ("Beitragsbemessungsgrenze"), which varies between 4,650 and 6,350 EUR per month. Following the procedure suggested by Dustmann, Ludsteck and Schönberg (2009) and CHK, we impute the upper tail of the wage distribution by running a series of Tobit regressions, allowing for a maximum degree of heterogeneity by fitting the model separately for region, gender, time, education levels, and eight five-year age groups. We also impute missing and inconsistent information in the education variable by using the methodology proposed in Fitzenberger, Osikominu and Völter (2006).

[10]The five-digit classification of KldB2010 distinguishes 1,286 occupations in our sample, which reduces the number of employees per occupation substantially. Nevertheless, we repeat our analyses using the five-digit classification scheme when we address robustness in Section 3.3.

firms. To add information on the firm structure, we use the ORBIS-ADIAB dataset, which provides a linking table between the IAB internal (system-free) establishment identifiers and the firm identifiers by BvD. The most important variables for the record linkage are the establishment and the company name, the legal form, the industry code, and the postal code.[11] Comprehensive documentation of the linking process is provided by Antoni et al. (2018). Firm-level financial data comes from the BvD Orbis database, and information on the three-digit WZ2008 industries (German Classification of Economic Activities 2008) of establishments is obtained from the IAB establishment history panel (Betriebs-Historik-Panel, BHP).[12]

We follow Song et al. (2019) and exclude firms with fewer than 20 employees in any sample year to ensure that firm-years with very few observations do not distort the calculation of the wage dispersion measures. We also exclude employee-establishment-years that are not linked to a firm. Unscaled financial variables are adjusted for inflation using the German consumer price index, and all continuous financial variables are winsorized at the 1st and 99th percentiles. Appendix B shows details on the definitions and data sources of variables. The final sample covers 69,268,888 employee-years, 16,630,960 unique employees, 205,858 establishments, and 87,440 firms between 2010 and 2016.

Table 1 provides descriptive statistics. On average, a full-time employee earns a log daily wage of 4.620 EUR in a given year. This corresponds to an average yearly income of 36,538 EUR (monthly: 3,045 EUR) for a full-time employee. The median employee works at an establishment with 170 full-time employees and 19 occupations. Furthermore, about 47% of employees work in firms with more than one establishment.

[11] The record linkage is carried out separately for the years 2014 and 2016. For 2010 to 2013 and 2015, we assume that the latest link of an establishment to a firm is still valid. A small share of around 3.8% of all establishment-years are mapped to multiple firms, for example because the establishment undergoes an ownership change, which we exclude.

[12] We largely follow the steps followed by Jäger, Schoefer and Heining (2019) to clean the firm-level financial data from Orbis and check its internal consistency. However, we only consider financial data for firm-years that report both total assets and sales.

3. Decomposition of within-firm wage inequality

3.1. Measurement of within-firm wage inequality

We calculate the overall within-establishment wage inequality as the variance of employees' log daily wages,

$$var_t^j(y_t^{i,j}) = \frac{1}{N_t^j}\sum_i (y_t^{i,j} - \bar{y}_t^j)^2, \tag{1}$$

where $y_t^{i,j}$ is the log daily wage of employee i at establishment j in year t. We find that the variance of log wages within establishments is on average 0.118. As the variance of log wages within and between establishments is 0.275 in our sample, this finding implies that the within-establishment wage inequality accounts for 43% of the overall wage inequality in the economy.[13]

3.2. Decomposition into HWI and VWI

To distinguish wage differences among employees with similar tasks from those among employees with different tasks, we would ideally use information on the exact tasks of employees. However, this information is not available. Alternatively, we rely on a fine-grained occupational classification scheme with 144 occupational groups and up to four different task complexity levels within these groups. In total, this scheme differentiates 431 occupation-task groups (see Section 2 for more details). Using this scheme, we decompose within-establishment wage differences into within- and between-occupation components as follows:

$$var_t^j(y_t^{i,j}) = \underbrace{\sum_o w_t^{o,j} \cdot var_t^{o,j}(y_t^{i,j})}_{\text{HWI}} + \underbrace{var_t^j(\bar{y}_t^{o,j})}_{\text{VWI}}, \tag{2}$$

where o denotes an occupation, $w_t^{o,j}$ the fraction of employees in occupation o at establishment j in year t, $var_t^{o,j}(y_t^{i,j})$ the wage dispersion within occupation o and establishment j, and $var_t^j(\bar{y}_t^{o,j})$ the variance of wages between occupations within an establishment. We find that the average HWI and VWI are 0.058

[13] Lochner, Seth and Wolter (2020) report a variance of log daily earnings of 0.291 for the universe of German full-time employees in the same time period. The similarity of their estimate to ours helps to mitigate concerns that our focus on establishments that are linked to a firm in the ORBIS-ADIAB dataset reduces the generalizability of our sample.

and 0.060, respectively. Thus, both contribute in (nearly) equal parts to the overall wage inequality within establishments (49.2 versus 50.8 percent).

3.3. HWI, VWI, and task heterogeneity

A potential concern with our measurement of HWI and VWI is that employees in the same occupation-task group could in fact perform different tasks, which would overestimate the role of HWI. To investigate this concern, we refine the occupational scheme. To this end, we use information on occupational subgroups, which allows us to distinguish 1,286 unique suboccupation-task groups.[14] The advantage of this refinement is that employees in the same occupation are even more likely to conduct the same tasks than in our main classification scheme. Intuitively, the more fine-grained the occupational classification scheme is, the less likely it is that wage variation within occupations captures VWI among employees who perform different tasks. The disadvantage, and the reason we do not use this scheme for the main analyses, is that the number of observations is relatively small for many establishment-occupation-years.

Table 3 shows the decomposition into HWI and VWI when using the full five-digit KldB2010 occupational classification scheme. The total wage variation within establishments, which is unaffected by the occupational classification scheme, is 0.118. Using the five-digit scheme, the within-occupation wage variance is 0.055, which implies that HWI accounts for 46.6% of the overall wage variance. The corresponding numbers for the three-plus-fifth-digit scheme are 0.058 and 49.2%, respectively. Thus, only 2.6 percentage points are additionally attributed to HWI when using the more detailed classification scheme. We conclude that task heterogeneity is unlikely to lead to a substantial over-estimation of HWI.

3.4. The role of employee characteristics

Next, we decompose the overall VWI and HWI into a component that is related to the remuneration of heterogeneous employee characteristics and a residuum. For this purpose, we apply a two-way fixed effects model with

[14] An example for a suboccupation-task group is "24232: Occupations in metalworking: cutting—skilled tasks", which corresponds to "242-2: Occupations in metalworking—skilled tasks" in our baseline classification. See Appendix A.1 for more details.

employer fixed effects, employee fixed effects, and controls for employees' age, education, and time trends, in the spirit of AKM.

3.4.1. Implementation of the wage model

Our specification of the AKM model assumes that the log real daily wage $y_t^{i,j}$ of worker i in establishment j is an additively separable function observable and unobservable establishment and worker characteristics. Specifically, α^i is a time-invariant employee fixed effect identified by employees who switch employers over time.[15] ψ^j is an establishment fixed effect.[16] X_t^i is an index of time-varying observable employee characteristics, including an unrestricted set of year dummies and quadratic and cubic terms in age[17] fully interacted with educational attainment. Finally, $r_t^{i,j}$ is an error term which represents the residual wage of employee i at establishment j. Accordingly, we run the following regression model on the largest connected set of establishments from 2010 to 2017 (those that are linked by employee transitions):

$$y_t^{i,j} = \alpha^i + \psi^j + \beta X_t^i + r_t^{i,j}. \tag{3}$$

Subsequently, we follow CHK and use the parameter estimates from Equation 3 to decompose the variance of wages into these components. The variance decomposition of overall wages within establishments can be written as

$$\begin{aligned} var_t^j(y_t^{i,j}) = & \\ & \overbrace{var_t^j(\alpha^i) + var_t^j(\beta X_t^i) + 2cov(\alpha^i, \beta X_t^i) + 2cov(\beta X_t^i, r_t^{i,j}) + 2cov(\alpha^i, r_t^{i,j})}^{\text{variation related to heterogeneous employee characteristics}} \\ & + \underbrace{var_t^j(r_t^{i,j})}_{\text{variation of residual wages}} . \end{aligned} \tag{4}$$

Note that the wage model estimates the remuneration for an employee's

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[15] To obtain estimates for the employee fixed effects of job stayers, we follow CHK. For each worker, we calculate the employee effect as the average difference of the observed individual wage from the estimated establishment effect (on the mover sample) and worker characteristics (using the coefficient estimates from the mover sample) across the number of years we observe an employee. See CHK's Online Appendix for computational details. In the time window 2010 to 2017, 37.4% of all employees switch employers at least once.

[16] The dependence of subscript j on employee i and year t is suppressed so that $j = J(i, t)$.

[17] As in CHK, the age variable is normalized to 40 years. See Card et al. (2018) and Song et al. (2019) for a discussion of this normalization.

characteristics by means of control variables (βX_t^i) and an employee fixed effect (α^i). This unobserved, permanent wage component is specific to an employee, but not to an employee-employer combination. The residual wage, however, captures wage adjustments which is specific to an employee-employer match, that is wage premia (or discounts) earned by employee i at establishment j, relative to the the baseline level $\alpha^i + \psi^j$.

3.4.2. Identifying assumptions

Denote N as the number of employees, J as the number of establishments, and T as the numbers of time periods. The wage model assumes strict exogeneity:

$$E(r_t^{i,j}|X_1^1, ..., X_T^N, \alpha^1, ..., \alpha^N, \psi^1, ..., \psi^J) = 0 \tag{5}$$

Equation 5 implies that employees' mobility decisions are independent of $r^{i,j}$, but may be a function of the unobservables α^i and ψ^j. The estimation of the AKM model is vulnerable to limited worker mobility resulting in an incidental parameter problem. In this regard, Andrews et al. (2012) show that the bias decreases with the number of employee transitions across employers. To assess the severeness of bias in our estimates, we apply the bias correction as described in Andrews et al. (2008). We find that the variance of the establishment fixed effects is 2.5% lower compared to our baseline estimation, and the variance of the employee fixed effects is 4% lower. The correlation between the fixed effects when using bias correction is 35%, as compared to 33% in our baseline AKM regression.[18] The very similar results using the bias correction method and the fact that we estimate the model on the entire universe of full-time employees mitigate concerns that our AKM estimation suffers from substantial limited mobility bias. This conclusion is in line with AKM, CHK, Song et al. (2019), and Lochner, Seth and Wolter (2020).[19]

[18] Kline, Saggio and Sølvsten (2020) offer an alternative approach of bias correction in AKM models, which, however, is computational very hard to implement for datasets of our size. Furthermore, as Borovičková and Shimer (2017) point out, there is no agreement yet about which (if any) of the approaches is superior.

[19] Bonhomme, Lamadon and Manresa (2019) propose a clustering approach to approximate the underlying, possibly continuous, distribution of unobserved firm heterogeneity. Specifically, these authors classify firms into a small number of k-means clusters. While this approach mitigates the potential incidental parameter problem, it is not practicable in our context as we are interested in wage inequality within establishments or firms, that is single units of production, not clusters of firms.

3.4.3. Results

The results are reported in Table 2 and graphically illustrated in Figure 1. 85% of the overall wage inequality within establishments is explained by the heterogeneity of employee characteristics. Most of the explanatory power derives from employee fixed effects, not from observable, time-variant employee characteristics. Regarding VWI, we find a very high explanatory power for the remuneration of heterogeneous employee characteristics, which accounts for over 95% of the wage variance between occupations.[20] Most of the explanatory power derives from employee fixed effects, while our controls for observable characteristics explain less than five percent. Regarding HWI, we find that remuneration for heterogeneous employee characteristics accounts for about three-quarters of the wage variation within occupations. Again, most of the explanatory power derives from employee fixed effects. The variance of the residual component accounts for about one-quarter of the HWI. [21]

4. What explains residual HWI?

Since the residual HWI accounts for one-quarter of the overall HWI, which is much higher as the residual VWI accounting only for five percent of the overall VWI, we try to better understand this component in this section. The residual HWI of an establishment j in year t can be written as

$$Residual\ HWI_t^j = \sum_o w_t^{o,j} \cdot var_t^{o,j}(r_t^{i,j}) \tag{6}$$

where $w_t^{o,j}$ is the fraction of employees and $var_t^{o,j}(r_t^{i,j})$ the residual wage dispersion within occupation o at establishment j in year t.

Further below in this section, we relate residual HWI to financial performance measures, which we observe from balance-sheet data at the firm level. Thus, we analogously, define residual HWI within a firm as

$$Residual\ HWI_t^f = \sum_o w_t^{o,f} \cdot var_t^{o,f}(r_t^{i,j}), \tag{7}$$

[20] This finding is in line with the conclusion of Mueller, Ouimet and Simintzi (2017b) that the higher wage inequality between different hierarchy levels in larger firms is related to differences in managerial talent.

[21] Related to our findings, Song et al. (2019) show that residual wage inequality accounts for approximately 25% of the wage dispersion within U.S. firms (from 2007 to 2013). Hence, the role of "residual" wage differences seems to be slightly more pronounced for U.S. firms.

where $w_t^{o,f}$ is the fraction of employees and $var_t^{o,f}(r_t^{i,j})$ is the residual wage dispersion in occupation o at firm f in year t.

Recall that the residual HWI captures the part of the HWI that cannot be explained by remuneration for heterogeneous employee characteristics. It is related to employee-employer-specific wage adjustments that may exist because different firms or establishments reward the same (hypothetical) employee differently. One potential explanation for this difference in compensation is that some firms use (more) pay-for-performance based compensation that rewards heterogeneous employee productivity, while others do not. Examples of those schemes include bonus payments and piece rates (Lazear, 2018). Additionally, base wage adjustments that are related to past or expected productivity, for example because of idiosyncratic match effects[22] between employees and employers, can also be seen as pay-for-performance based compensation. The existence of those schemes creates dispersed wages within occupations due to performance differences across employees and over time (Seiler, 1984; Lemieux, MacLeod and Parent, 2009).

4.1. Profit sharing and residual HWI

The first hypothesis to test is whether a greater extent of profit sharing (as a form of pay-for-performance schemes) in establishments is related with higher residual HWI. To this end, we use survey data on the use of profit-sharing programs in establishments which originates from the IAB establishment panel (Betriebspanel, BP)—a representative establishment-level survey for Germany. Among other things, these data include the fraction of employees that participate in profit sharing, the existence of written employee assessment, and whether or not employees have clear written targets.[23] For legal reasons, we cannot link the survey data with information on firm structures. Hence, we only observe employee-establishment information in the survey sample.[24]

To measure the above mentioned relationship, we regress residual HWI on

[22] Those match effects occur, for example, due to complementarities between employees and firms or drifts in the portable component of employees' earnings power (see CHK).

[23] Bechmann et al. (2017) provide further details on the dataset. The question on profit sharing was asked in 2011, 2013, and 2015. The questions on written employee assessment and written targets were asked in 2011 and 2013.

[24] We observe information on profit sharing for about 3.3 million employee-years, 2.0 million employees, and 16,553 establishments. On average, 37% of employees participate in the establishment's profit-sharing program.

the fraction of employees who participate in a profit-sharing program:

$$Residual\ HWI_t^j = \alpha + \beta profit\ sharing_t^j + \gamma log(emp_t^j) + \lambda^j \cdot \tau_t + \kappa^j \cdot \tau_t + \epsilon_t^j, \quad (8)$$

where *profit sharing*$_t^j$ is the share of employees in establishment j who participate in a profit-sharing program in year t, λ^j denotes establishment-industry dummies (based on three-digit WZ2008 industries), κ^j establishment-county dummies (based on regional districts, so-called "Landkreise," which are comparable to counties in the U.S.), and τ_t year dummies. α is a constant, and ϵ is the error term. We estimate this model on the employee-year level and cluster standard errors at the establishment-level.

The results are shown in Panel A of Table 4. We start with a simple specification without fixed effects in Column 1. The coefficient estimate for β is 0.0064 (t-value of 4.75) in this specification. The coefficient estimate remains unchanged once we add year fixed effects in Column 2. The magnitude of the coefficient estimate drops to 0.0023 (t-value of 8.21) once we control for county-year- and industry-year fixed effects in Column 3. Additionally controlling for establishment size further reduces the magnitude of the coefficient estimate to 0.0016 (t-value of 5.70), which implies that residual HWI increases by 12.3%, relative to its mean,[25] for a hypothetical establishment that changes the share of employees participating in a profit-sharing program from zero to one.

The establishments are also asked whether written employee assessments and written target agreements with employees exist. Both aspects of human resource management are indirectly related to incentive pay: employees' wages can only be linked to their performance if their performance is measured and if there are objective criteria that determine their performance (see Bloom and Van Reenen (2011) for more background on performance pay and human resource management).[26]

The results for employee assessment are shown in Panel B of Table 4. We again start with a simple specification without fixed effects in Column 1. The

[25]The mean of the residual HWI for the survey data sample on profit sharing is 0.013, and the standard deviation is 0.0097.

[26]We observe information on employee assessment and target setting for about 2.2 million employee-years, 1.6 million employees, and 14 thousand establishments. On average, 77% of employees experience written employee assessments. The corresponding percentage for written employee targets is 69%.

coefficient estimate for β is 0.0034 (t-value of 3.88). The coefficient estimate remains unchanged when we add year fixed effects in Column 2. The magnitude of the coefficient estimate drops substantially once we control for county-year- and industry-year fixed effects in Column 3, and it becomes statistically insignificant when we additionally control for establishment size in Column 4. These results point to a positive correlation between residual HWI and the existence of formal employee assessment. However, this correlation seems to be substantially driven by the size differences between establishments.

In Panel C of Table 4, we focus on written employee targets using the same regression specifications as for profit sharing and employee assessments. The coefficient estimate is 0.0039 (t-value of 4.05) in Column 1. The coefficient estimates remains unaltered when we introduce year-fixed effects in the next column. In Column 3, we add county-year and industry-year fixed effects, which reduces the coefficient estimate to 0.0014 (t-value of 4.28). Additionally controlling for establishment size further reduces the estimate to 0.00074 (t-value of 2.16). This coefficient estimate indicates that residual HWI increases by 5.7%, relative to its mean, when an establishment introduces written employee targets. The results indicate that residual HWI is positively correlated with the existence of written employee targets.

Intuitively, our results show that performance-pay-schemes (proxied by the prevalence of profit sharing and written employee assessment and targets) are related to wages differences among seemingly similar workers (in terms of their un-/observable characteristics) within the same occupation/task-group of the same establishment. Although we do not interpret these results as causal effects, these results are consistent with previous literature which shows that performance-pay has direct effects on the wage distribution (see among others Lemieux, MacLeod and Parent, 2009). In the next section, we examine potential pathways in greater detail.

4.2. Financial performance and residual HWI

The implied mechanism through which profit sharing affects residual HWI is firm profitability: if firms are more profitable, they share more of the profits with their productive employees, leading to more residual HWI. To test this mechanism, we link residual HWI to measures for firm performance. Our regression models exploit cross-sectional and time-series variation in residual HWI and firm outcomes. The regression specification for firm f and year t can be written as

$$residual\ HWI_t^f = \alpha + \beta Financial\ performance_t^f + \vec{\gamma}\vec{C}_t^f + \lambda^f \cdot \tau_t + \epsilon_t^f, \qquad (9)$$

where *financial performance*$_t^f$ is a measure for the financial performance of firm f in year t, $\vec{C}^k$ is a set of firm-level control variables (natural logarithm of total assets, leverage, tangibility, cash holdings, and a public listing dummy), τ_t year dummies, λ^f industry dummies (based on the industry of the firm), and ϵ is an error term. Note that we observe firm outcomes only at the firm level and not at the establishment level. Hence, it is not possible to exploit differences between establishments within firms for these tests.[27]

We use four measures for firms' financial performance: EBITDA, EBIT, net income, and cash flow. All measures are scaled by total assets (please see Appendix B for their construction). Table 5 presents the results. For all measures, we find a positive and statistically significant coefficient estimate of β, indicating a positive realtionship between financial performance and residual HWI. In terms of economic magnitude, the estimates imply that a one-standard-deviation increase in EBITDA per assets increases residual HWI by about 3.5%, relative to its mean.[28] Wages among employees who perform similar tasks and have similar characteristics seem to be more unequal if firms are more profitable, which is consistent with a pay-for-performance based explanation of residual HWI.

4.3. Residual HWI and monitoring costs

Our second strategy to shed light on the relevance of pay-for-performance for residual HWI exploits that incentive pay is conceptually linked to monitoring costs. For this purpose, we next assess the relation between residual HWI and monitoring costs which we measure by the task complexitity of occupations and the size of establishments and firms.

[27]It would be interesting to explore the sensitivity of residual HWI on financial performance conditional on the presence of profit sharing and human resource policies (recall the results from the previous section). However, for legal reasons, we cannot link the data on firm performance with the survey data.

[28]The mean of the residual HWI for the regression sample is 0.017 and the standard deviation is 0.012.

4.3.1. Conceptual framework

Agency problems between employers and employees may arise because their interests diverge: employers want employees to maximize their efforts, but there is evidence that employees' utility is negatively related to effort (Ross, 1973). Two potential solutions are monitoring and pay methods that reward employee performance. Their relative attractiveness depends on the monitoring costs of a firm. If monitoring costs are low, the firm is likely better off monitoring its employees instead of using incentive-pay schemes, which also come at a cost for firms.[29] However, if monitoring costs are high, incentive pay becomes more attractive for firms than monitoring. In this context, the model of Prendergast (2002) predicts that the use of incentive pay should increase with monitoring costs, and the model of Lazear (1981) suggests that age-earnings profiles should increase with monitoring costs. The empirical literature, which finds that the use of incentive pay increases with monitoring costs, provides support for these predictions (e.g., Brown, 1990; Drago and Heywood, 1995; Barth et al., 2008).

What determines monitoring costs? Two important factors that we can exploit empirically are the observability of employees' actions and uncertainty about their optimal actions (Holmstrom, 1979; Prendergast, 2002). The observability of employees' actions depends, among other characteristics, on the size of an establishment. Garen (1985) develops a model in which compensation contracts differ between large and small firms because of their differences in monitoring costs. An important ingredient of his model is that larger firms have higher costs of acquiring information about employees and lower accuracy when screening employees. Uncertainty about optimal actions is closely related to the characteristics of employees' tasks (Holmstrom and Milgrom, 1991), and firms choose compensation policies that fit those characteristics (Holmstrom and Milgrom, 1994; MacLeod and Parent, 2012). In this context, the Prendergast (2002) model predicts that incentive pay is more likely in occupations that involve complex tasks that are more difficult to monitor due to greater uncertainty regarding employees' optimal actions.

[29]For instance, incentive pay can lead to the manipulation of performance measures or the deceiving of customers (Baker, Gibbons and Murphy, 1994).

4.3.2. Task complexity of occupations

To assess the task complexity of an occupation, we rely on two classification schemes. First, we use the scheme proposed by Autor, Levy and Murnane (2003). These authors Autor, Levy and Murnane (2003) distinguish five types of tasks: analytical nonroutine, interactive nonroutine, cognitive routine (which is a combination of analytical and interactive routine). Routine and nonroutine tasks differ in whether or not the optimal actions to carry out these tasks follow an explicit procedure. Analytical tasks involve formal analytic skills (e.g., engineering and science), while interactive tasks require managerial or interpersonal skills (e.g., managing a team). Manual tasks, such as cleaning, driving of vehicles, or combining different parts in an assembly line, are relatively straightforward to perform. Task complexity is highest in nonroutine analytical and nonroutine interactive tasks, followed by routine cognitive tasks, and lowest in nonroutine and routine manual tasks.[30] The second classification for task complexity, which we refer to as "occupational complexity," is based on the fifth digit of the KldB2010 occupation code, which indicates the level of task complexity of an occupation-task group (see Appendix A for more details).

We first sort occupations by their median residual HWI in Figure 2(a).[31] For each occupation, we show the classification of its main task and its occupational complexity. The main tasks of the five occupations with the highest residual HWI are all classified as nonroutine tasks that require analytical skills, and these occupations are all classified as highly complex. All five occupations with the lowest residual HWI have mainly manual tasks (four routine, one nonroutine).

Figures 2(b) to (f) illustrate the relation between occupations' task composition and residual HWI. The horizontal axis shows the fraction of tasks of an occupation that are analytical nonroutine (subfigure b), interactive nonroutine (c), cognitive routine (d), manual nonroutine (e), or manual routine (f). Ev-

[30]We obtain information on the main task of occupations and their task composition from Dengler, Matthes and Paulus (2014), who follow the approach of Autor, Levy and Murnane (2003). We use the classification from 2013.

[31]The occupation-level residual wage variance is calculated as the employee weighted average of all establishment-occupation residual wage variances. Please note that we focus on the 50 largest occupations, which account for approximately 70% of the employee-years in our dataset, for the analyses in Figure 2.

ery dot in the figures represents one specific occupation, and we add a linear regression line with a 90% confidence interval. We find that the fraction of analytical nonroutine tasks and interactive nonroutine tasks has a positive relationship with residual HWI.[32] For all other tasks, we detect a flat or negative relationship. These results indicate that residual HWI is higher in occupations with more complex tasks that are more costly to monitor due to their higher uncertainty about optimal actions.

4.3.3. Firm and establishment size

Next, we present a graphical analysis of the relationship between residual wage inequality and firm size. In Figure 3, we sort firms into deciles based on their number of full-time employees and calculate, for each decile, the average within-establishment variance of residual wages. In Figure 3(a), we measure size and wage inequality on the firm level and find that residual wage inequality increases with firm size, from about 0.0138 in decile one to 0.0265 in decile ten. All of this increase is driven by residual HWI, which more than doubles from decile one to ten, while residual VWI declines with size. Using establishment size instead of firm size in Figure 3(b) leads to similar results. These findings is in line with the view that residual HWI captures pay-for-performance pay since the observability of employees' actions is lower in larger firms, which increases their monitoring costs.

4.3.4. Regression analysis

We conduct regressions to further analyze the relationship between residual HWI, task complexity, and firm size. First, we regress the residual HWI of a firm, which is calculated over all its employees and establishments, on the number of full-time employees:

$$Residual\ HWI_t^f = \alpha + \beta log(emp_t^f) + \lambda^f \cdot \tau_t + \kappa^f \cdot \tau_t + \epsilon_t^f, \tag{10}$$

where $log(emp_t^f)$ is the size of firm f in year t, α a constant, and ϵ the error term. We also include county-year fixed effects $\kappa^f \cdot \tau_t$ based on regional districts (so-called "Landkreise," which are comparable to counties in the U.S.) and

[32] These patterns cannot be explained by higher task heterogeneity in occupations with analytical or interactive tasks. Appendix D shows that the relationship between (residual) HWI and task concentration is flat or even slightly positive.

industry-year fixed effects $\lambda^f \cdot \tau_t$ based on three-digit WZ2008 industries. We estimate this model on the employee-year level and cluster standard errors at the firm-level. The results are presented in Column 1 of Table 6. The coefficient estimate for $log(emp_t^f)$ is positive and statistically significant at the 1% level. The magnitude of β is 0.0020, which indicates that the residual HWI is about 12.5% higher, relative to its mean, for a firm that has twice as many employees.[33]

In Columns 2 to 4, we analyze measures for task complexity. Again, we use the average fraction of analytical nonroutine and interactive nonroutine tasks in a firm, which is based on the classification scheme of Autor, Levy and Murnane (2003), and the average occupational complexity of a firm, which is based on the fifth digit of the KldB2010 occupational classification scheme. The regression specification follows Equation 10, except that we replace $log(emp_t^f)$ with our task complexity measures. We find that residual HWI increases with the average task complexity of a firm. The coefficient estimate for β indicates that a one-standard-deviation increase in the fraction of analytical nonroutine tasks is associated with a 19.7% higher residual HWI, relative to its mean. The corresponding values for interactive nonroutine and occupational complexity are 10.1% and 17.1%. In Column 5, we include all measures for size and task complexity in the regression at the same time. All of them remain positive and statistically significant at the 1% level.

Next, we use the establishment structure of multi-establishment firms to analyze differences in size and task complexity across establishments of the same firm. In this specification, we additionally include firm-year fixed effects, which ensure that the estimation of the parameter of interest, β, is based on differences between establishments within the same firm.[34] This within-firm estimation controls for all time-constant and time-varying firm-specific factors and helps to mitigate concerns that unobservable firm heterogeneity could drive our results. The regression specification for the establishment size

[33]Note that there is a positive relation between the size of the firm and the size of its occupations. To assess the role of occupation size, we add the logarithm of the mean number of employees in an occupation to the regression model in Column 1. It turns out that, on average, about half of the firm-size effect originates from larger occupations in larger firms.

[34]See Giroud and Mueller (2015) for a similar approach in the context of labor reallocation within firms.

analysis can be written as

$$Residual\ HWI_t^j = \alpha + \beta log(emp_t^j) + \lambda^j \cdot \tau_t + \kappa^j \cdot \tau_t + \eta^f \cdot \tau_t + \epsilon_t^j, \qquad (11)$$

where $log(emp_t^j)$ is the size of establishment j in year t and $\eta^f \cdot \tau_t$ a firm-year fixed effect. The results are reported in Table 7. We find that residual HWI is higher in larger establishments and those that have more complex tasks. The magnitudes of the estimates for β are similar to the ones we documented before. Overall, our results show that residual HWI increases with firms' monitoring costs, which is in line with the view that it captures incentive pay.

5. Conclusion

Using a newly available dataset that links employee-, establishment-, and firm-level information from Germany, we find that (i) HWI and VWI contribute equally to the overall wage inequality within establishments, (ii) heterogeneous employee characteristics explain about 95 percent of the overall VWI and three-quarters of the overall HWI, and (iii) pay-for-performance schemes are a plausible explanation for residual HWI, that is, wage inequality among employees conducting similar tasks after controlling for heterogeneous employee characteristics.

These findings suggest that heterogeneous employee characteristics can nearly fully explain wage differences among employees who perform *different* tasks within firms (VWI). Among employees who perform *similar* tasks (HWI), however, heterogeneous employee characteristics explain a substantially lower fraction of the wage differences (about three-quarters). The remaining unexplained quarter is positively correlated with the existence of profit sharing programs, written employee assessments, written employee targets, firm profitability, and monitoring costs measured by the task complexity of an occupation and the size of an establishment or firm. Our evidence affirms that pay-for-performance schemes are a plausible explanation for the unexplained quarter of HWI. This incentive function suggests that HWI fulfills an important function for firms that should not be overlooked in the public debate.

For policy makers, our results imply that horizontal wage inequality that is not related to employee characteristics likely fulfills an important role for firms by reducing agency conflicts between owners/managers and employees. In this regard, policy initiatives that target wage inequality need to carefully consider firms' need for such incentives devices. For academics, our results indicate that the application of residual HWI as proxy for pay-for-performance schemes provides an interesting avenue for further investigation. Although the calculation of our measure requires rich linked employee-employer data, using residual HWI as complement or substitute to survey data to measure incentive pay might provide a more comprehensive understanding of the interplay between incentives, employees, and firms.

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Figures

Figure 1

Decomposition of within-establishment wage differences

This figure visualizes the decomposition of the within-establishment variance of wages, wages after controlling for observable employee characteristics ("wages - Xb"), and wages after controlling for observable and unobservable employee characteristics ("residual wages") into a vertical (between occupation-task groups) and a horizontal (within occupation-task groups) component. The exact values of the decomposition can be found in Table 2. A detailed description of all variables can be found in Appendix B.

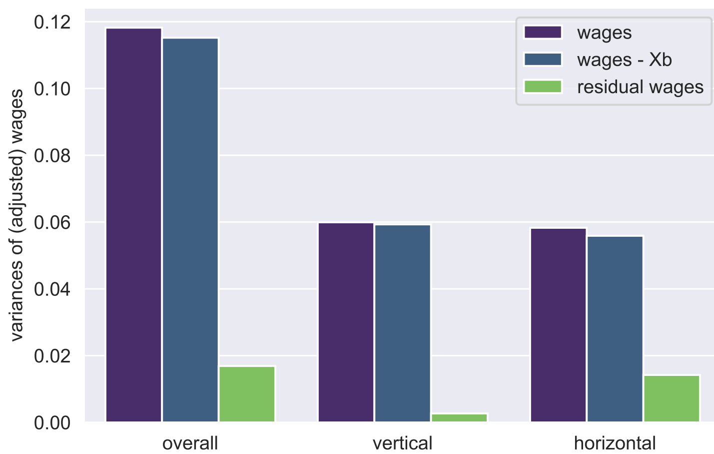
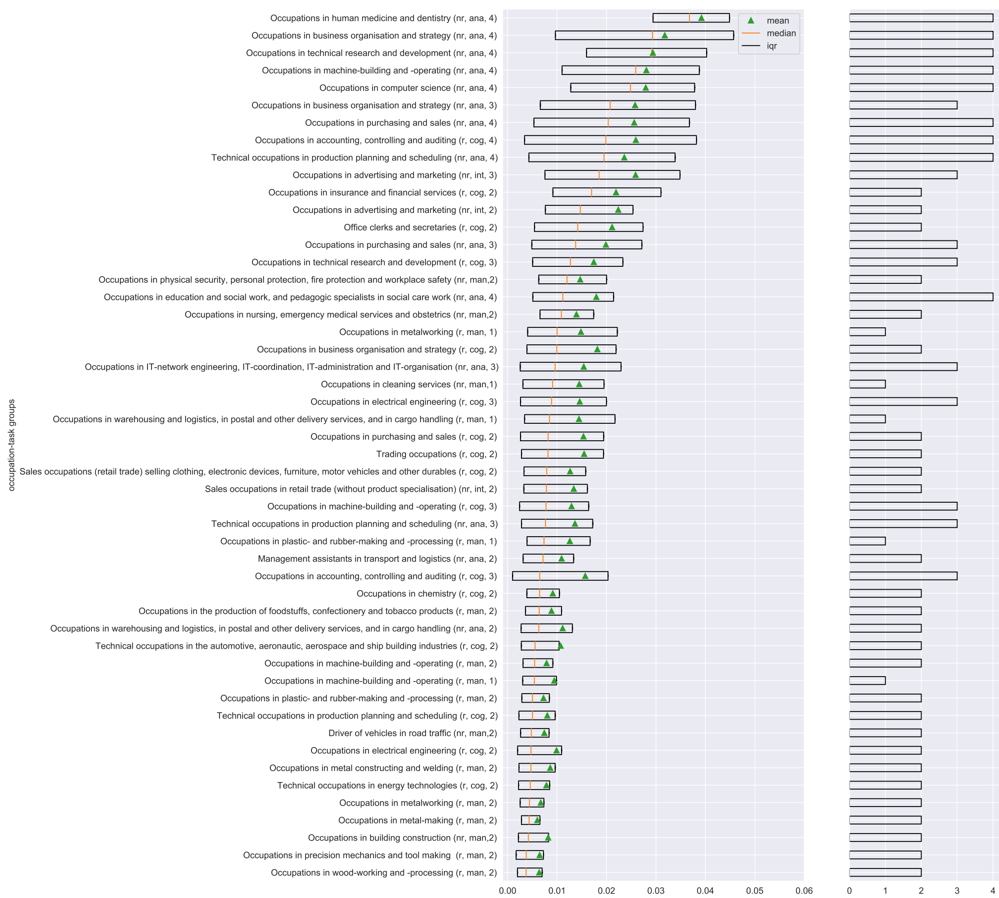


Figure 2

Residual HWI and occupation-task groups

This figure shows the residual horizontal wage inequality (HWI) in different occupation-task groups. We limit this analysis to the 50 most common occupation-task groups in our sample; they account for approximately 70% of the employee-years. Subfigure (a) presents the occupation-task groups sorted by the median value of the residual HWI measure. In parentheses, we show the task classification according to Autor, Levy and Murnane (2003) and the task complexity level according to the fifth digit of the KldB2010 occupational classification scheme. *nr* denotes a nonroutine task, *r* a routine task, *ana* an analytical task, *int* an interactive task, *cog* a cognitive task, *man* a manual task, *1* unskilled/semi-skilled tasks, *2* skilled tasks, *3* complex tasks, and *4* highly complex tasks. Subfigures (b) to (f) illustrate the relation between the residual HWI and the share of analytic nonroutine, interactive nonroutine, cognitive routine, manual nonroutine, and manual routine tasks using linear regression with 90% confidence interval. A detailed description of all variables can be found in Appendix B.

(a) 50 largest occupations sorted by median residual HWI



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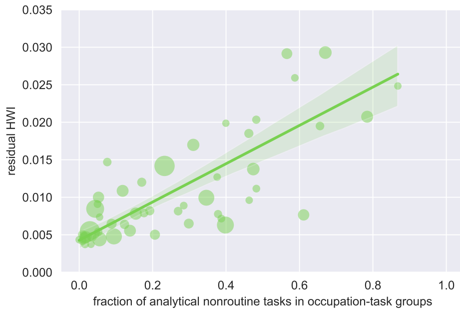
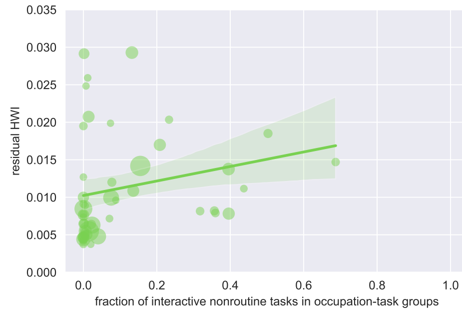
(b) analytical nonroutine tasks

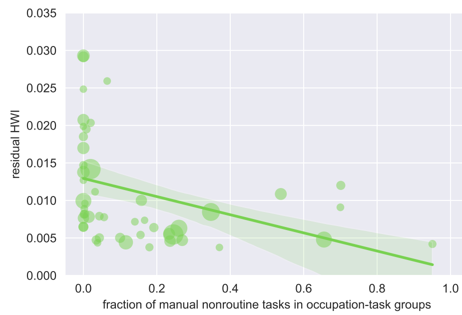


(c) interactive nonroutine tasks



(d) cognitive routine tasks

(e) manual nonroutine tasks



(f) manual routine tasks

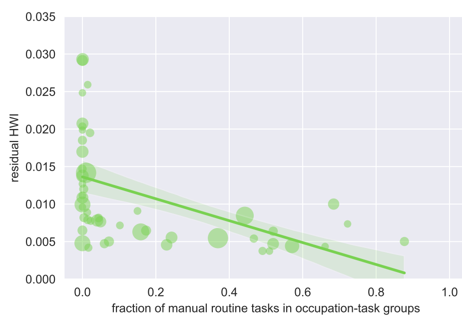
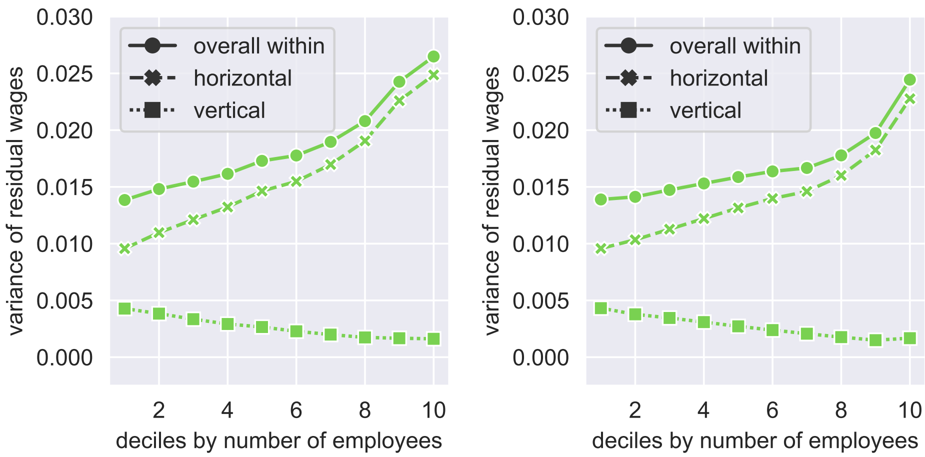


Figure 3

Size and within wage inequality

This figure presents, for each size decile, the decomposition of the mean value of the within-establishment residual wage variance into a horizontal and a vertical component. In Subfigure (a), size and wage inequality are measured on the firm level. In Subfigure (b), the measurement is on the establishment level. To construct the size deciles, we sort establishments or firms based on their number of full-time employees. A detailed description of all variables can be found in Appendix B.

(a) residual wage inequality$_{firm}$ **(b)** residual wage inequality$_{estab}$



Tables

Table 1
Descriptive statistics

This table presents descriptive statistics. The sample consists of 69,268,888 employee-years, 16,630,960 individual employees, 205,858 establishments, and 87,440 firms. Reported are the number of observations (Obs), mean value (Mean), standard deviation (SD), 25% percentile (25th), median (50th), and 75% percentile (75th). A detailed description of all variables can be found in Appendix B.

	Obs	Mean	SD	25th	50th	75th
wage	69,268,888	4.620	0.524	4.287	4.612	4.940
HWI$_{estab}$	69,175,635	0.058	0.047	0.028	0.047	0.075
HWI$_{firm}$	69,268,888	0.063	0.045	0.033	0.053	0.080
residual HWI$_{estab}$	69,175,635	0.014	0.013	0.006	0.011	0.019
residual HWI$_{firm}$	69,268,888	0.016	0.012	0.007	0.013	0.022
number of occupation-task groups	69,268,888	26.052	23.012	10.000	19.000	35.000
empl$_{estab}$	69,268,888	1284	4932	61	166	521
empl$_{firm}$	69,268,888	5814	19588	93	298	1341
multi-establishment firm	69,268,888	0.470	0.499	0.000	0.000	1.000
number of establishments	69,268,888	44.808	264.195	1.000	1.000	5.000
analytical nonroutine tasks	69,260,523	0.261	0.236	0.053	0.204	0.398
interactive nonroutine tasks	69,260,523	0.095	0.145	0.000	0.015	0.155
occupational complexity	69,268,888	2.322	0.869	2.000	2.000	3.000
listing dummy	31,734,998	0.138	0.344	0.000	0.000	0.000
ebitda to assets$_{firm}$	27,701,999	0.106	0.120	0.039	0.088	0.159
ebit to assets$_{firm}$	20,476,558	0.072	0.124	0.015	0.060	0.122
net income to assets$_{firm}$	22,387,610	0.038	0.092	0.005	0.036	0.070
cash flow to assets$_{firm}$	27,510,562	0.075	0.086	0.035	0.066	0.108

Table 2
Decomposition of within-establishment wage differences

This table presents the decomposition of the within-establishment variance of wages, the within-establishment variance of wages within occupation-task groups (HWI), and the within-establishment variance of wages between occupation-task groups (VWI). Within-establishment wage inequality, HWI, and VWI are decomposed into the variances and covariances of the parameter estimates from the AKM-type regression as stated in Equation 4. A detailed description of all variables can be found in Appendix B.

	overall within		HWI		VWI	
	mean	share	mean	share	mean	share
var(wage)	0.118	1.000	0.058	1.000	0.060	1.000
var(person FE)	0.098	0.828	0.044	0.750	0.054	0.904
var(Xb)	0.009	0.077	0.007	0.125	0.002	0.030
var(residual)	0.017	0.143	0.014	0.244	0.003	0.045
2cov(person FE, Xb)	-0.006	-0.050	-0.004	-0.076	-0.001	-0.025
2cov(person FE, residual)	0.000	0.004	-0.002	-0.035	0.002	0.041
2cov(Xb, residual)	-0.000	-0.001	-0.000	-0.008	0.000	0.005

Table 3

Decomposition of within-establishment wage differences: five-digit Kldb2010

This table presents the decomposition of the within-establishment variance of wages, the within-establishment variance of wages within suboccupation-task groups (HWI), and the within-establishment variance of wages between suboccupation-task groups (VWI) using the five-digit KldB2010 occupational callssification scheme, which distinguishes 1,286 suboccupation-task groups. Our baseline decomposition in Table 2 uses the first three digits plus the fifth digit of the KldB2010 classification and distinguishes 426 occupation-task groups. A detailed description of all variables can be found in Appendix B.

	overall		HWI		VWI	
	mean	share	mean	share	mean	share
var(wage)	0.118	1.000	0.055	1.000	0.063	1.000
var(person FE)	0.098	0.828	0.041	0.749	0.057	0.897
var(Xb)	0.009	0.077	0.007	0.128	0.002	0.032
var(residual)	0.017	0.143	0.014	0.252	0.003	0.048
2cov(person FE, Xb)	-0.006	-0.050	-0.004	-0.081	-0.001	-0.022
2cov(person FE, residual)	0.000	0.004	-0.002	-0.038	0.003	0.040
2cov(Xb, residual)	-0.000	-0.001	-0.000	-0.009	0.000	0.005

Table 4

Profit sharing, human resources management, and residual HWI

The dependent variable is an establishment's residual horizontal wage inequality (HWI). Residual HWI captures wage differences among employees in the same occupation-task group due to employee-employer-specific wage adjustments. Profit sharing is measured as the number of employees who participate in profit sharing in an establishment, divided by the establishment's total number of employees. Written employee assessment is a dummy variable that indicates whether an establishment conducts written assessments of employees. Written employee targets is a dummy variable that indicates whether an establishment uses written target agreements with employees. Profit sharing, written employee assessment, and written employee targets are based on survey data (see Section 4.1 for more details.) The regression models are estimated on the employee-year level. T-statistics based on robust standard errors clustered at the establishment level are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. A detailed description of all variables can be found in Appendix B.

	(1)	(2)	(3)	(4)
Panel A: Profit sharing				
profit sharing	0.0064***	0.0064***	0.0023***	0.0016***
	(4.75)	(4.67)	(8.21)	(5.70)
$\log(\text{empl})_{estab}$				0.0012***
				(13.76)
Year FE	No	Yes	Yes	Yes
County x year FE	No	No	Yes	Yes
Industry x year FE	No	No	Yes	Yes
Obs	3,257,088	3,257,088	3,256,666	3,256,666
R2	0.10	0.10	0.54	0.56
Panel B: Written employee assessments				
written employee assessment	0.0034***	0.0034***	0.00075**	-0.00013
	(3.88)	(3.80)	(2.29)	(-0.38)
$\log(\text{empl})_{estab}$				0.0014***
				(12.23)
Year FE	No	Yes	Yes	Yes
County x year FE	No	No	Yes	Yes
Industry x year FE	No	No	Yes	Yes
Obs	2,197,831	2,197,831	2,197,660	2,197,660
R2	0.02	0.03	0.54	0.56
Panel C: Written employee targets				
written employee targets	0.0039***	0.0039***	0.0014***	0.00074**
	(4.05)	(3.92)	(4.28)	(2.16)
$\log(\text{empl})_{estab}$				0.0013***
				(12.06)
Year FE	No	Yes	Yes	Yes
County x year FE	No	No	Yes	Yes
Industry x year FE	No	No	Yes	Yes
Obs	2,197,526	2,197,526	2,197,355	2,197,355
R2	0.03	0.04	0.55	0.56

Table 5
Residual HWI and financial performance

The dependent variable is a firm's residual horizontal wage inequality (HWI). Residual HWI captures wage differences among employees in the same occupation-task group due to employee-employer-specific wage adjustments. The measure for financial performance is indicated in each column. The regression models are estimated on the employee-year level. T-statistics based on robust standard errors clustered at the firm level are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. A detailed description of all variables can be found in Appendix B.

	(1)	(2)	(3)	(4)
ebitda/assets	0.0049***			
	(4.42)			
ebit/assets		0.0030***		
		(3.43)		
net income/assets			0.0036**	
			(2.34)	
cash flow/assets				0.0043***
				(2.93)
log(total assets)	0.0021***	0.0018***	0.0021***	0.0021***
	(18.94)	(16.95)	(17.82)	(18.76)
leverage	-0.0015***	-0.0012***	-0.0013***	-0.0016***
	(-3.45)	(-3.34)	(-2.88)	(-3.56)
tangibility	-0.0099***	-0.0077***	-0.0080***	-0.0097***
	(-13.41)	(-13.79)	(-11.54)	(-12.68)
cash holdings	-0.0020*	-0.0013	-0.0019	-0.0019*
	(-1.90)	(-1.57)	(-1.64)	(-1.77)
listing dummy	0.0025**	0.0016**	0.0023*	0.0024**
	(2.16)	(1.98)	(1.91)	(2.09)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry x year FE	Yes	Yes	Yes	Yes
Obs	25,125,090	18,536,099	20,533,326	25,046,989
R2	0.50	0.40	0.52	0.50

Table 6

Firm size, task complexity, and residual HWI

The dependent variable is a firm's residual horizontal wage inequality (HWI). Residual HWI captures wage differences among employees in the same occupation-task group due to employee-employer-specific wage adjustments. The task-based measures, which follow Autor, Levy and Murnane (2003), capture the average share of analytical nonroutine and interactive nonroutine tasks in a firm. Occupational complexity is based on the fifth digit of the KldB2010 occupational classification scheme and captures the average task complexity level of occupation-task groups in a firm. The regression models are estimated on the employee-year level. T-statistics based on robust standard errors clustered at the firm level are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. A detailed description of all variables can be found in Appendix B.

	(1)	(2)	(3)	(4)	(5)
log(empl)$_{firm}$	0.0020***				0.0019***
	(20.81)				(20.22)
analytical nonroutine tasks$_{firm}$		0.024***			0.015***
		(22.00)			(9.21)
interactive nonroutine tasks$_{firm}$			0.017***		0.012***
			(10.04)		(6.66)
occupational complexity$_{firm}$				0.0055***	0.0016***
				(19.46)	(3.98)
Year FE	Yes	Yes	Yes	Yes	Yes
County x year FE	Yes	Yes	Yes	Yes	Yes
Industry x year FE	Yes	Yes	Yes	Yes	Yes
Obs	69,250,918	69,250,918	69,250,918	69,250,918	69,250,918
R2	0.44	0.42	0.40	0.42	0.47

Table 7
Establishment size, task complexity, and residual HWI

The dependent variable is an establishment's residual horizontal wage inequality (HWI). Residual HWI captures wage differences among employees in the same occupation-task group due to employee-employer-specific wage adjustments. The task-based measures, which follow Autor, Levy and Murnane (2003), capture the average share of analytical nonroutine and interactive nonroutine tasks in an establishment. Occupational complexity is based on the fifth digit of the KldB2010 classification scheme and captures the average task complexity level of occupation-task groups in an establishment. The regression models are estimated on the employee-year level. T-statistics based on robust standard errors clustered at the firm level are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. A detailed description of all variables can be found in Appendix B.

	(1)	(2)	(3)	(4)	(5)
log(empl)$_{estab}$	0.0017***				0.0018***
	(13.11)				(14.84)
analytical nonroutine tasks$_{estab}$		0.031***			0.023***
		(12.71)			(8.25)
interactive nonroutine tasks$_{estab}$			0.021***		0.018***
			(9.49)		(9.50)
occupational complexity$_{estab}$				0.0075***	0.0015***
				(12.29)	(2.67)
Year FE	Yes	Yes	Yes	Yes	Yes
County x year FE	Yes	Yes	Yes	Yes	Yes
Industry x year FE	Yes	Yes	Yes	Yes	Yes
Firm x year FE	Yes	Yes	Yes	Yes	Yes
Obs	32,428,714	32,428,709	32,428,709	32,428,714	32,428,709
R2	0.67	0.67	0.66	0.67	0.68

Appendices

A. The KldB2010 occupational classification scheme

A.1. Description

The KldB2010 occupational classification scheme is published by the Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung, IAB). KldB stands for "Klassifikation der Berufe" (classification of occupations), and 2010 indicates the version of the classification scheme.

The KldB2010 scheme uses five digits to define occupations, and its structure is as follows: the first digit indicates the occupational area, the first two digits the occupational main group, the first three digits the occupational group, and the first four digits the occupational sub-group. The fifth digit specifies the task level on a scale from one to four: one stands for unskilled or semi-skilled tasks, two for skilled tasks, three for complex tasks, and four for highly complex tasks.[35] The combination of occupational subgroup and task level defines a suboccupation-task group, but not all task levels exist for all groups. In total, there are 10 occupational groups, 37 occupational main groups, 144 occupational groups, 700 occupational sub-groups, and 1,286 suboccupation-task groups.

To illustrate the classification scheme, consider occupational group 2: Occupations in production of raw materials and goods, and manufacturing. For this occupational group, there are nine main groups, for example, 22: Occupations in plastic-making and -processing, and wood-working and -processing, 23: Occupations in paper-making and -processing, printing, and in technical media design, and 24: Occupations in metal-making and -working, and in metal

[35] Level one requires "no vocational qualification, or regular one-year vocational training," two "at least two years of vocational training, also graduation from vocational school," three "qualification as master craftsman or technician or equivalent technical school or college graduation, also graduation from a professional academy or university bachelor's degree," and four "completed university studies of at least four year" (Paulus and Matthes, 2013).

construction. The last main group is further divided into five occupational groups, for example, 241: Occupations in metal-making, 243: Occupations in treatment of metal surfaces, and 242: Occupations in metalworking. The last occupational group is then divided into six sub-groups, for example, 2421: Occupations in metalworking: non-cutting, 2422: Occupations in metalworking: grinding, and 2423: Occupations in metalworking: cutting. For the last sub-group, the classification scheme distinguishes two task levels: 24232: Occupations in metalworking: cutting—skilled tasks and 24233: Occupations in metalworking: cutting—complex tasks.[36]

The KldB2010 three-plus-fifth-digit classification, which we use in our main analyses, is a combination of the 3-digit occupational group and the fifth digit, which indicates the task level. This scheme distinguishes 144 occupational groups with up to four task levels, which yields 431 occupation-task groups. The full list of these groups is shown in A.2. We use the five-digit classification scheme, which distinguishes all 1,286 occupations, as the robustness test in Section 3.3.

[36]Please note that "unskilled or semi-skilled tasks" and "highly complex tasks" do not exist for 2423: Occupations in metalworking: cutting.

A.2. List of occupations (KldB2010 three-plus-fifth digit)

111-1	Occupations in farming - unskilled/semiskilled tasks
111-2	Occupations in farming - skilled tasks
111-3	Occupations in farming - complex tasks
111-4	Occupations in farming - highly complex tasks
112-1	Occupations in animal husbandry - unskilled/semiskilled tasks
112-2	Occupations in animal husbandry - skilled tasks
112-3	Occupations in animal husbandry - complex tasks
112-4	Occupations in animal husbandry - highly complex tasks
113-2	Occupations in horsekeeping - skilled tasks
113-3	Occupations in horsekeeping - complex tasks
113-4	Occupations in horsekeeping - highly complex tasks
114-1	Occupations in fishing - unskilled/semiskilled tasks
114-2	Occupations in fishing - skilled tasks
114-3	Occupations in fishing - complex tasks
114-4	Occupations in fishing - highly complex tasks
115-1	Occupations in animal care - unskilled/semiskilled tasks
115-2	Occupations in animal care - skilled tasks
115-3	Occupations in animal care - complex tasks
115-4	Occupations in animal care - highly complex tasks
116-2	Occupations in vini- and viticulture - skilled tasks
116-3	Occupations in vini- and viticulture - complex tasks
116-4	Occupations in vini- and viticulture - highly complex tasks
117-1	Occupations in forestry, hunting and landscape preservation - unskilled/semiskilled tasks
117-2	Occupations in forestry, hunting and landscape preservation - skilled tasks
117-3	Occupations in forestry, hunting and landscape preservation - complex tasks
117-4	Occupations in forestry, hunting and landscape preservation - highly complex tasks
121-1	Occupations in gardening - unskilled/semiskilled tasks
121-2	Occupations in gardening - skilled tasks
121-3	Occupations in gardening - complex tasks
121-4	Occupations in gardening - highly complex tasks
122-2	Occupations in floristry - skilled tasks
122-3	Occupations in floristry - complex tasks
122-4	Occupations in floristry - highly complex tasks
211-1	Occupations in underground and surface mining and blasting engineering - unskilled/semiskilled tasks
211-2	Occupations in underground and surface mining and blasting engineering - skilled tasks
211-3	Occupations in underground and surface mining and blasting engineering - complex tasks
211-4	Occupations in underground and surface mining and blasting engineering - highly complex tasks
212-1	Conditioning and processing of natural stone and minerals, production of building materials - unskilled/semiskilled tasks
212-2	Conditioning and processing of natural stone and minerals, production of building materials - skilled tasks
212-3	Conditioning and processing of natural stone and minerals, production of building materials - complex tasks
213-1	Occupations in industrial glass-making and -processing - unskilled/semiskilled tasks
213-2	Occupations in industrial glass-making and -processing - skilled tasks
213-3	Occupations in industrial glass-making and -processing - complex tasks
214-1	Occupations in industrial ceramic-making and -processing - unskilled/semiskilled tasks
214-2	Occupations in industrial ceramic-making and -processing - skilled tasks
214-3	Occupations in industrial ceramic-making and -processing - complex tasks
221-1	Occupations in plastic- and rubber-making and -processing - unskilled/semiskilled tasks
221-2	Occupations in plastic- and rubber-making and -processing - skilled tasks
221-3	Occupations in plastic- and rubber-making and -processing - complex tasks
221-4	Occupations in plastic- and rubber-making and -processing - highly complex tasks
222-1	Occupations in colour coating and varnishing - unskilled/semiskilled tasks
222-2	Occupations in colour coating and varnishing - skilled tasks
222-3	Occupations in colour coating and varnishing - complex tasks
222-4	Occupations in colour coating and varnishing - highly complex tasks
223-1	Occupations in wood-working and -processing - unskilled/semiskilled tasks
223-2	Occupations in wood-working and -processing - skilled tasks
223-3	Occupations in wood-working and -processing - complex tasks
223-4	Occupations in wood-working and -processing - highly complex tasks

231-1	Technical occupations in paper-making and -processing and packaging - unskilled/semiskilled tasks
231-2	Technical occupations in paper-making and -processing and packaging - skilled tasks
231-3	Technical occupations in paper-making and -processing and packaging - complex tasks
231-4	Technical occupations in paper-making and -processing and packaging - highly complex tasks
232-2	Occupations in technical media design - skilled tasks
232-3	Occupations in technical media design - complex tasks
232-4	Occupations in technical media design - highly complex tasks
233-2	Occupations in photography and photographic technology - skilled tasks
233-3	Occupations in photography and photographic technology - complex tasks
233-4	Occupations in photography and photographic technology - highly complex tasks
234-1	Occupations in printing technology, print finishing, and book binding - unskilled/semiskilled tasks
234-2	Occupations in printing technology, print finishing, and book binding - skilled tasks
234-3	Occupations in printing technology, print finishing, and book binding - complex tasks
234-4	Occupations in printing technology, print finishing, and book binding - highly complex tasks
241-1	Occupations in metal-making - unskilled/semiskilled tasks
241-2	Occupations in metal-making - skilled tasks
241-3	Occupations in metal-making - complex tasks
241-4	Occupations in metal-making - highly complex tasks
242-1	Occupations in metalworking - unskilled/semiskilled tasks
242-2	Occupations in metalworking - skilled tasks
242-3	Occupations in metalworking - complex tasks
242-4	Occupations in metalworking - highly complex tasks
243-1	Occupations in treatment of metal surfaces - unskilled/semiskilled tasks
243-2	Occupations in treatment of metal surfaces - skilled tasks
243-3	Occupations in treatment of metal surfaces - complex tasks
243-4	Occupations in treatment of metal surfaces - highly complex tasks
244-1	Occupations in metal constructing and welding - unskilled/semiskilled tasks
244-2	Occupations in metal constructing and welding - skilled tasks
244-3	Occupations in metal constructing and welding - complex tasks
244-4	Occupations in metal constructing and welding - highly complex tasks
245-1	Occupations in precision mechanics and tool making - unskilled/semiskilled tasks
245-2	Occupations in precision mechanics and tool making - skilled tasks
245-3	Occupations in precision mechanics and tool making - complex tasks
245-4	Occupations in precision mechanics and tool making - highly complex tasks
251-1	Occupations in machine-building and -operating - unskilled/semiskilled tasks
251-2	Occupations in machine-building and -operating - skilled tasks
251-3	Occupations in machine-building and -operating - complex tasks
251-4	Occupations in machine-building and -operating - highly complex tasks
252-1	Technical occupations in the automotive, aeronautic, aerospace and ship building industries - unskilled/semiskilled tasks
252-2	Technical occupations in the automotive, aeronautic, aerospace and ship building industries - skilled tasks
252-3	Technical occupations in the automotive, aeronautic, aerospace and ship building industries - complex tasks
252-4	Technical occupations in the automotive, aeronautic, aerospace and ship building industries - highly complex tasks
261-2	Occupations in mechatronics, automation and control technology - skilled tasks
261-3	Occupations in mechatronics, automation and control technology - complex tasks
261-4	Occupations in mechatronics, automation and control technology - highly complex tasks
262-2	Technical occupations in energy technologies - skilled tasks
262-3	Technical occupations in energy technologies - complex tasks
262-4	Technical occupations in energy technologies - highly complex tasks
263-1	Occupations in electrical engineering - unskilled/semiskilled tasks
263-2	Occupations in electrical engineering - skilled tasks
263-3	Occupations in electrical engineering - complex tasks
263-4	Occupations in electrical engineering - highly complex tasks
271-3	Occupations in technical research and development - complex tasks
271-4	Occupations in technical research and development - highly complex tasks
271-2	Occupations in technical research and development - skilled tasks
272-2	Draftspersons, technical designers, and model makers - skilled tasks
272-3	Draftspersons, technical designers, and model makers - complex tasks
272-4	Draftspersons, technical designers, and model makers - highly complex tasks
273-2	Technical occupations in production planning and scheduling - skilled tasks
273-3	Technical occupations in production planning and scheduling - complex tasks

273-4	Technical occupations in production planning and scheduling - highly complex tasks
281-1	Occupations in textile making - unskilled/semiskilled tasks
281-2	Occupations in textile making - skilled tasks
281-3	Occupations in textile making - complex tasks
281-4	Occupations in textile making - highly complex tasks
282-2	Occupations in the production of clothing and other textile products - skilled tasks
282-3	Occupations in the production of clothing and other textile products - complex tasks
282-4	Occupations in the production of clothing and other textile products - highly complex tasks
282-1	Occupations in the production of clothing and other textile products - unskilled/semiskilled tasks
283-1	Occupations in leather- and fur-making and -processing - unskilled/semiskilled tasks
283-2	Occupations in leather- and fur-making and -processing - skilled tasks
283-3	Occupations in leather- and fur-making and -processing - complex tasks
283-4	Occupations in leather- and fur-making and -processing - highly complex tasks
291-2	Occupations in beverage production - skilled tasks
291-3	Occupations in beverage production - complex tasks
291-4	Occupations in beverage production - highly complex tasks
292-1	Occupations in the production of foodstuffs, confectionery and tobacco products - unskilled/semiskilled tasks
292-2	Occupations in the production of foodstuffs, confectionery and tobacco products - skilled tasks
292-3	Occupations in the production of foodstuffs, confectionery and tobacco products - complex tasks
292-4	Occupations in the production of foodstuffs, confectionery and tobacco products - highly complex tasks
293-1	Cooking occupations - unskilled/semiskilled tasks
293-2	Cooking occupations - skilled tasks
293-3	Cooking occupations - complex tasks
293-4	Cooking occupations - highly complex tasks
311-2	Occupations in construction scheduling and supervision, and architecture - skilled tasks
311-3	Occupations in construction scheduling and supervision, and architecture - complex tasks
311-4	Occupations in construction scheduling and supervision, and architecture - highly complex tasks
312-2	Occupations in surveying and cartography - skilled tasks
312-3	Occupations in surveying and cartography - complex tasks
312-4	Occupations in surveying and cartography - highly complex tasks
321-1	Occupations in building construction - unskilled/semiskilled tasks
321-2	Occupations in building construction - skilled tasks
321-3	Occupations in building construction - complex tasks
321-4	Occupations in building construction - highly complex tasks
322-1	Occupations in civil engineering - unskilled/semiskilled tasks
322-2	Occupations in civil engineering - skilled tasks
322-3	Occupations in civil engineering - complex tasks
322-4	Occupations in civil engineering - highly complex tasks
331-1	Floor layers - unskilled/semiskilled tasks
331-2	Floor layers - skilled tasks
331-3	Floor layers - complex tasks
332-1	Painters & varnishers, plasterers, occ. in waterp. of build., preservation of structures & wooden build. comp.- unskilled/semiskilled tasks
332-2	Painters & varnishers, plasterers, occ. in waterproofing of buildings, preservation of structures & wooden build. comp. - skilled tasks
332-3	Painters & varnishers, plasterers, occ. in waterproofing of buildings, preservation of structures & wooden build. comp. - complex tasks
333-1	Occupations in interior construction & dry walling, insulation, carpentry, glazing, roller shutter & jalousie inst. - unskilled/semiskilled tasks
333-2	Occupations in interior construction & dry walling, insulation, carpentry, glazing, roller shutter & jalousie installation - skilled tasks
333-3	Occupations in interior construction & dry walling, insulation, carpentry, glazing, roller shutter & jalousie installation - complex tasks
341-2	Occupations in building services engineering - skilled tasks
341-3	Occupations in building services engineering - complex tasks
341-4	Occupations in building services engineering - highly complex tasks
342-1	Occupations in plumping, sanitation, heating, ventilating, and air conditioning - unskilled/semiskilled tasks
342-2	Occupations in plumping, sanitation, heating, ventilating, and air conditioning - skilled tasks
342-3	Occupations in plumping, sanitation, heating, ventilating, and air conditioning - complex tasks
342-4	Occupations in plumping, sanitation, heating, ventilating, and air conditioning - highly complex tasks
343-1	Occupations in building services and waste disposal - unskilled/semiskilled tasks
343-2	Occupations in building services and waste disposal - skilled tasks
343-3	Occupations in building services and waste disposal - complex tasks
343-4	Occupations in building services and waste disposal - highly complex tasks
411-3	Occupations in mathematics and statistics - complex tasks
411-4	Occupations in mathematics and statistics - highly complex tasks

412-3	Occupations in biology - complex tasks
412-4	Occupations in biology - highly complex tasks
412-2	Occupations in biology - skilled tasks
413-3	Occupations in chemistry - complex tasks
413-4	Occupations in chemistry - highly complex tasks
413-1	Occupations in chemistry - unskilled/semiskilled tasks
413-2	Occupations in chemistry - skilled tasks
414-3	Occupations in physics - complex tasks
414-4	Occupations in physics - highly complex tasks
414-2	Occupations in physics - skilled tasks
421-2	Occupations in geology, geography and meteorology - skilled tasks
421-3	Occupations in geology, geography and meteorology - complex tasks
421-4	Occupations in geology, geography and meteorology - highly complex tasks
422-2	Occupations in environmental protection engineering - skilled tasks
422-3	Occupations in environmental protection engineering - complex tasks
422-4	Occupations in environmental protection engineering - highly complex tasks
423-2	Occupations in environmental protection management and environmental protection consulting - skilled tasks
423-3	Occupations in environmental protection management and environmental protection consulting - complex tasks
423-4	Occupations in environmental protection management and environmental protection consulting - highly complex tasks
431-2	Occupations in computer science - skilled tasks
431-3	Occupations in computer science - complex tasks
431-4	Occupations in computer science - highly complex tasks
432-4	Occupations in IT-system-analysis, IT-application-consulting and IT-sales - highly complex tasks
432-3	Occupations in IT-system-analysis, IT-application-consulting and IT-sales - complex tasks
433-3	Occupations in IT-network engineering, IT-coordination, IT-administration and IT-organisation - complex tasks
433-4	Occupations in IT-network engineering, IT-coordination, IT-administration and IT-organisation - highly complex tasks
434-2	Occupations in software development and programming - skilled tasks
434-3	Occupations in software development and programming - complex tasks
434-4	Occupations in software development and programming - highly complex tasks
511-2	Technical occupations in railway, aircraft and ship operation - skilled tasks
511-3	Technical occupations in railway, aircraft and ship operation - complex tasks
511-4	Technical occupations in railway, aircraft and ship operation - highly complex tasks
512-2	Occupations in the inspection and maintenance of traffic infrastructure - skilled tasks
512-3	Occupations in the inspection and maintenance of traffic infrastructure - complex tasks
512-4	Occupations in the inspection and maintenance of traffic infrastructure - highly complex tasks
513-1	Occupations in warehousing and logistics, in postal and other delivery services, and in cargo handling - unskilled/semiskilled tasks
513-2	Occupations in warehousing and logistics, in postal and other delivery services, and in cargo handling - skilled tasks
513-3	Occupations in warehousing and logistics, in postal and other delivery services, and in cargo handling - complex tasks
513-4	Occupations in warehousing and logistics, in postal and other delivery services, and in cargo handling - highly complex tasks
514-2	Service occupations in passenger traffic - skilled tasks
514-3	Service occupations in passenger traffic - complex tasks
515-3	Occupations in traffic surveillance and control - complex tasks
515-4	Occupations in traffic surveillance and control - highly complex tasks
515-2	Occupations in traffic surveillance and control - skilled tasks
516-3	Management assistants in transport and logistics - complex tasks
516-4	Management assistants in transport and logistics - highly complex tasks
516-2	Management assistants in transport and logistics - skilled tasks
521-2	Driver of vehicles in road traffic - skilled tasks
522-2	Drivers of vehicles in railway traffic - skilled tasks
523-3	Aircraft pilots - complex tasks
523-4	Aircraft pilots - highly complex tasks
524-3	Ship's officers and masters - complex tasks
524-4	Ship's officers and masters - highly complex tasks
524-2	Ship's officers and masters - skilled tasks
525-2	Drivers and operators of construction and transportation vehicles and equipment - skilled tasks
525-1	Drivers and operators of construction and transportation vehicles and equipment - unskilled/semiskilled tasks
525-3	Drivers and operators of construction and transportation vehicles and equipment - complex tasks
531-1	Occupations in physical security, personal protection, fire protection and workplace safety - unskilled/semiskilled tasks
531-2	Occupations in physical security, personal protection, fire protection and workplace safety - skilled tasks
531-3	Occupations in physical security, personal protection, fire protection and workplace safety - complex tasks

531-4	Occupations in physical security, personal protection, fire protection and workplace safety - highly complex tasks
532-2	Occupations in police and criminal investigation, jurisdiction and the penal institution - skilled tasks
532-3	Occupations in police and criminal investigation, jurisdiction and the penal institution - complex tasks
532-4	Occupations in police and criminal investigation, jurisdiction and the penal institution - highly complex tasks
532-1	Occupations in police and criminal investigation, jurisdiction and the penal institution - unskilled/semiskilled tasks
533-2	Occupations in occupational health and safety administration, public health authority, and disinfection - skilled tasks
533-3	Occupations in occupational health and safety administration, public health authority, and disinfection - complex tasks
533-4	Occupations in occupational health and safety administration, public health authority, and disinfection - highly complex tasks
541-1	Occupations in cleaning services - unskilled/semiskilled tasks
541-2	Occupations in cleaning services - skilled tasks
541-3	Occupations in cleaning services - complex tasks
611-2	Occupations in purchasing and sales - skilled tasks
611-3	Occupations in purchasing and sales - complex tasks
611-4	Occupations in purchasing and sales - highly complex tasks
612-3	Trading occupations - complex tasks
612-4	Trading occupations - highly complex tasks
612-2	Trading occupations - skilled tasks
613-2	Occupations in real estate and facility management - skilled tasks
613-3	Occupations in real estate and facility management - complex tasks
613-4	Occupations in real estate and facility management - highly complex tasks
621-1	Sales occupations in retail trade (without product specialisation) - unskilled/semiskilled tasks
621-2	Sales occupations in retail trade (without product specialisation) - skilled tasks
621-3	Sales occupations in retail trade (without product specialisation) - complex tasks
621-4	Sales occupations in retail trade (without product specialisation) - highly complex tasks
622-2	Sales occupations (retail trade) selling clothing, electronic devices, furniture, motor vehicles and other durables - skilled tasks
623-1	Sales occupations (retail) selling foodstuffs - unskilled/semiskilled tasks
623-2	Sales occupations (retail) selling foodstuffs - skilled tasks
624-2	Sales occupations (retail) selling drugstore products, pharmaceuticals, medical supplies and healthcare goods - skilled tasks
625-2	Sales occupations (retail) selling books, art, antiques, musical instruments, recordings or sheet music - skilled tasks
625-3	Sales occupations (retail) selling books, art, antiques, musical instruments, recordings or sheet music - complex tasks
625-4	Sales occupations (retail) selling books, art, antiques, musical instruments, recordings or sheet music - highly complex tasks
631-2	Occupations in tourism and the sports (and fitness) industry - skilled tasks
631-3	Occupations in tourism and the sports (and fitness) industry - complex tasks
631-4	Occupations in tourism and the sports (and fitness) industry - highly complex tasks
632-2	Occupations in hotels - skilled tasks
632-3	Occupations in hotels - complex tasks
632-1	Occupations in hotels - unskilled/semiskilled tasks
632-4	Occupations in hotels - highly complex tasks
633-1	Gastronomy occupations - unskilled/semiskilled tasks
633-2	Gastronomy occupations - skilled tasks
633-3	Gastronomy occupations - complex tasks
633-4	Gastronomy occupations - highly complex tasks
634-1	Occupations in event organisation and management - unskilled/semiskilled tasks
634-2	Occupations in event organisation and management - skilled tasks
634-3	Occupations in event organisation and management - complex tasks
634-4	Occupations in event organisation and management - highly complex tasks
711-4	Managing directors and executive board members - highly complex tasks
712-4	Legislators and senior officials of special interest organisations - highly complex tasks
713-2	Occupations in business organisation and strategy - skilled tasks
713-3	Occupations in business organisation and strategy - complex tasks
713-4	Occupations in business organisation and strategy - highly complex tasks
714-1	Office clerks and secretaries - unskilled/semiskilled tasks
714-2	Office clerks and secretaries - skilled tasks
714-3	Office clerks and secretaries - complex tasks
714-4	Office clerks and secretaries - highly complex tasks
715-2	Occupations in human resources management and personnel service - skilled tasks
715-3	Occupations in human resources management and personnel service - complex tasks
715-4	Occupations in human resources management and personnel service - highly complex tasks
721-2	Occupations in insurance and financial services - skilled tasks
721-3	Occupations in insurance and financial services - complex tasks

721-4	Occupations in insurance and financial services - highly complex tasks
722-2	Occupations in accounting, controlling and auditing - skilled tasks
722-3	Occupations in accounting, controlling and auditing - complex tasks
722-4	Occupations in accounting, controlling and auditing - highly complex tasks
723-2	Occupations in tax consultancy - skilled tasks
723-3	Occupations in tax consultancy - complex tasks
723-4	Occupations in tax consultancy - highly complex tasks
731-4	Occupations in legal services, jurisdiction, and other officers of the court - highly complex tasks
731-2	Occupations in legal services, jurisdiction, and other officers of the court - skilled tasks
731-3	Occupations in legal services, jurisdiction, and other officers of the court - complex tasks
732-1	Occupations in public administration - unskilled/semiskilled tasks
732-2	Occupations in public administration - skilled tasks
732-3	Occupations in public administration - complex tasks
732-4	Occupations in public administration - highly complex tasks
733-2	Occupations in media, documentation and information services - skilled tasks
733-3	Occupations in media, documentation and information services - complex tasks
733-4	Occupations in media, documentation and information services - highly complex tasks
811-2	Doctors' receptionists and assistants - skilled tasks
811-3	Doctors' receptionists and assistants - complex tasks
812-2	Laboratory occupations in medicine - skilled tasks
812-3	Laboratory occupations in medicine - complex tasks
812-4	Laboratory occupations in medicine - highly complex tasks
813-1	Occupations in nursing, emergency medical services and obstetrics - unskilled/semiskilled tasks
813-2	Occupations in nursing, emergency medical services and obstetrics - skilled tasks
813-3	Occupations in nursing, emergency medical services and obstetrics - complex tasks
813-4	Occupations in nursing, emergency medical services and obstetrics - highly complex tasks
814-4	Occupations in human medicine and dentistry - highly complex tasks
815-4	Occupations in veterinary medicine and non-medical animal health practitioners - highly complex tasks
815-2	Occupations in veterinary medicine and non-medical animal health practitioners - skilled tasks
816-4	Occupations in psychology and non-medical psychotherapy - highly complex tasks
816-3	Occupations in psychology and non-medical psychotherapy - complex tasks
817-2	Occupations in non-medical therapy and alternative medicine - skilled tasks
817-3	Occupations in non-medical therapy and alternative medicine - complex tasks
817-4	Occupations in non-medical therapy and alternative medicine - highly complex tasks
818-4	Occupations in pharmacy - highly complex tasks
818-2	Occupations in pharmacy - skilled tasks
818-3	Occupations in pharmacy - complex tasks
821-1	Occupations in geriatric care - unskilled/semiskilled tasks
821-2	Occupations in geriatric care - skilled tasks
821-3	Occupations in geriatric care - complex tasks
821-4	Occupations in geriatric care - highly complex tasks
822-2	Occupations providing nutritional advice or health counselling, and occupations in wellness - skilled tasks
822-3	Occupations providing nutritional advice or health counselling, and occupations in wellness - complex tasks
822-4	Occupations providing nutritional advice or health counselling, and occupations in wellness - highly complex tasks
823-1	Occupations in body care - unskilled/semiskilled tasks
823-2	Occupations in body care - skilled tasks
823-3	Occupations in body care - complex tasks
824-2	Occupations in funeral services - skilled tasks
824-3	Occupations in funeral services - complex tasks
824-4	Occupations in funeral services - highly complex tasks
825-2	Technical occupations in medicine, orthopaedic and rehabilitation - skilled tasks
825-3	Technical occupations in medicine, orthopaedic and rehabilitation - complex tasks
825-4	Technical occupations in medicine, orthopaedic and rehabilitation - highly complex tasks
831-1	Occupations in education and social work, and pedagogic specialists in social care work - unskilled/semiskilled tasks
831-2	Occupations in education and social work, and pedagogic specialists in social care work - skilled tasks
831-3	Occupations in education and social work, and pedagogic specialists in social care work - complex tasks
831-4	Occupations in education and social work, and pedagogic specialists in social care work - highly complex tasks
832-1	Occupations in housekeeping and consumer counselling - unskilled/semiskilled tasks
832-2	Occupations in housekeeping and consumer counselling - skilled tasks
832-3	Occupations in housekeeping and consumer counselling - complex tasks

833-4	Occupations in theology and church community work - highly complex tasks
833-2	Occupations in theology and church community work - skilled tasks
833-3	Occupations in theology and church community work - complex tasks
841-4	Teachers in schools of general education - highly complex tasks
841-3	Teachers in schools of general education - complex tasks
842-3	Teachers for occupation-specific subjects at vocational schools and in-company instructors in vocational training - complex tasks
842-4	Teachers for occupation-specific subjects at vocational schools and in-company instructors in vocational training - highly complex tasks
843-4	Teachers and researcher at universities and colleges - highly complex tasks
844-4	Teachers at educational institutions other than schools (except driving, flying and sports instructors) - highly complex tasks
844-2	Teachers at educational institutions other than schools (except driving, flying and sports instructors) - skilled tasks
844-3	Teachers at educational institutions other than schools (except driving, flying and sports instructors) - complex tasks
845-3	Driving, flying and sports instructors at educational institutions other than schools - complex tasks
845-4	Driving, flying and sports instructors at educational institutions other than schools - highly complex tasks
911-4	Occupations in philology - highly complex tasks
912-4	Occupations in the humanities - highly complex tasks
912-3	Occupations in the humanities - complex tasks
913-4	Occupations in the social sciences - highly complex tasks
913-1	Occupations in the social sciences - unskilled/semiskilled tasks
913-2	Occupations in the social sciences - skilled tasks
913-3	Occupations in the social sciences - complex tasks
914-4	Occupations in economics - highly complex tasks
921-2	Occupations in advertising and marketing - skilled tasks
921-3	Occupations in advertising and marketing - complex tasks
921-4	Occupations in advertising and marketing - highly complex tasks
922-3	Occupations in public relations - complex tasks
922-4	Occupations in public relations - highly complex tasks
923-2	Occupations in publishing and media management - skilled tasks
923-3	Occupations in publishing and media management - complex tasks
923-4	Occupations in publishing and media management - highly complex tasks
924-2	Occupations in editorial work and journalism - skilled tasks
924-3	Occupations in editorial work and journalism - complex tasks
924-4	Occupations in editorial work and journalism - highly complex tasks
931-2	Occupations in product and industrial design - skilled tasks
931-3	Occupations in product and industrial design - complex tasks
931-4	Occupations in product and industrial design - highly complex tasks
932-2	Occupations in interior design, visual marketing, and interior decoration - skilled tasks
932-3	Occupations in interior design, visual marketing, and interior decoration - complex tasks
932-4	Occupations in interior design, visual marketing, and interior decoration - highly complex tasks
933-2	Occupations in artisan craftwork and fine arts - skilled tasks
933-3	Occupations in artisan craftwork and fine arts - complex tasks
933-4	Occupations in artisan craftwork and fine arts - highly complex tasks
934-2	Artisans designing ceramics and glassware - skilled tasks
934-3	Artisans designing ceramics and glassware - complex tasks
935-2	Artisans working with metal - skilled tasks
935-3	Artisans working with metal - complex tasks
935-4	Artisans working with metal - highly complex tasks
936-2	Occupations in musical instrument making - skilled tasks
936-3	Occupations in musical instrument making - complex tasks
936-4	Occupations in musical instrument making - highly complex tasks
941-4	Musicians, singers and conductors - highly complex tasks
941-3	Musicians, singers and conductors - complex tasks
942-4	Actors, dancers, athletes and related occupations - highly complex tasks
942-2	Actors, dancers, athletes and related occupations - skilled tasks
942-3	Actors, dancers, athletes and related occupations - complex tasks
943-3	Presenters and entertainers - complex tasks
943-4	Presenters and entertainers - highly complex tasks
943-2	Presenters and entertainers - skilled tasks
944-2	Occupations in theatre, film and television productions - skilled tasks
944-3	Occupations in theatre, film and television productions - complex tasks
944-4	Occupations in theatre, film and television productions - highly complex tasks

945-2	Occupations in event technology, cinematography, and sound engineering - skilled tasks
945-3	Occupations in event technology, cinematography, and sound engineering - complex tasks
945-4	Occupations in event technology, cinematography, and sound engineering - highly complex tasks
946-2	Occupations in stage, costume and prop design, - skilled tasks
946-3	Occupations in stage, costume and prop design, - complex tasks
946-4	Occupations in stage, costume and prop design, - highly complex tasks
947-4	Technical and management occupations in museums and exhibitions - highly complex tasks
947-2	Technical and management occupations in museums and exhibitions - skilled tasks
947-3	Technical and management occupations in museums and exhibitions - complex tasks
011-4	Commissioned officers - highly complex tasks
012-3	Senior non-commissioned officers and higher - complex tasks
013-2	Junior non-commissioned officers - skilled tasks
014-2	Armed forces personnel in other ranks - skilled tasks

Appendix B
Definition of Variables

Variable	Description
Wage and AKM components	
wage	Imputed real log daily wage. The base year for the inflation adjustment using the Consumer Price Index is 2010. Source: BeH.
person FE	Person fixed effect from the AKM-type regression. The implementation and interpretation of the AKM-type regression are explained in detail in Section 3.4.1.
establishment FE	Establishment fixed effect from the AKM-type regression. The implementation and interpretation of the AKM-type regression are explained in detail in Section 3.4.1.
Xb	Combination of life cycle and aggregate factors from the AKM-type regression. The implementation and interpretation of the AKM-type regression are explained in detail in Section 3.4.1.
residual (wage)	Residual wage from the AKM-type regression. The implementation and interpretation of the AKM-type regression are explained in detail in Section 3.4.1.
Occupational characteristics	
HWI	Variance of wages within an occupation-task group and establishment. The calculation of the horizontal wage inequality (HWI) is explained in Section 3.2.
residual HWI	Variance of residual wages within an occupation-task group and establishment. The calculation of the residual horizontal wage inequality (HWI) is explained in detail in Section 3.2.
analytical nonroutine tasks	Fraction of analytical nonroutine tasks in an occupation. Source: Dengler, Matthes and Paulus (2014).
interactive nonroutine tasks	Fraction of interactive nonroutine tasks in an occupation. Source: Dengler, Matthes and Paulus (2014).
occupational complexity	Level of task complexity of an occupation-task group according to the KldB2010 occupational classification scheme. *1* stands for unskilled/semi-skilled tasks, *2* for skilled tasks, *3* for complex tasks, and *4* for highly complex tasks. Source: BeH, BHP.
Establishment characteristics	
HWI_{estab}	Mean within occupation-task group variance of wages within an establishment. The calculation of the horizontal wage inequality (HWI) is explained in detail in Section 3.2.
residual HWI_{estab}	Mean within occupation-task group variance of residual wages within an establishment. The calculation of the residual horizontal wage inequality (HWI) is explained in detail in Section 3.2.

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Variable	Description
number of occupation-task groups	Number of occupation-task groups using the first three digits plus the fifth digit of the KldB 2010 classification scheme. Source: BeH.
empl_{estab}	Number of full-time employees in an establishment. Source: BeH, BHP.
analytical nonroutine tasks_{estab}	Mean fraction of analytical nonroutine tasks in an establishment. Source: BeH, Dengler, Matthes and Paulus (2014).
interactive nonroutine tasks_{estab}	Fraction of interactive nonroutine tasks in an establishment. Source: BeH, Dengler, Matthes and Paulus (2014).
occupational $\text{complexity}_{estab}$	Mean occupational complexity in an establishment. Source: BeH, BHP.
profit sharing	Number of employees in an establishment who participate in profit sharing, divided by total number of employees of the establishment. Source: BP.
written employee assessment	Dummy variable that indicates whether the establishment conducts written assessments of employees. Source: BP.
written employee targets	Dummy variable that indicates whether an establishment has written target agreements with employees. Source: BP.
Firm characteristics	
HWI_{firm}	Mean within occupation-task group variance of wages within a firm. The calculation of the horizontal wage inequality (HWI) is explained in detail in Section 3.2.
residual HWI_{firm}	Mean within occupation-task group variance of residual wages within a firm. The calculation of the residual horizontal wage inequality (HWI) is explained in detail in Section 3.2
empl_{firm}	Number of full-time employees in a firm. Source: BeH, BHP, Orbis-ADIAB.
multi-establishment firm	Dummy indicating whether the establishment belongs to a firm with multiple establishments. Source: Oribs-ADIAB.
number of establishments	Number of establishments that belong to a firm. Source: Oribs-ADIAB.
analytical nonroutine tasks_{firm}	Mean fraction of analytical nonroutine tasks in a firm. Source: BeH, Orbis-ADIAB, Dengler, Matthes and Paulus (2014).
interactive nonroutine tasks_{firm}	Fraction of interactive nonroutine tasks in a firm. Source: BeH, Orbis-ADIAB, Dengler, Matthes and Paulus (2014).
occupational complexity_{firm}	Mean occupational complexity in a firm. Source: BeH, Orbis-ADIAB.
ebitda to assets_{firm}	Ratio of a firm's ebitda to total assets. Source: Orbis.
ebit to assets_{firm}	Ratio of a firm's ebit to total assets. Source: Orbis.

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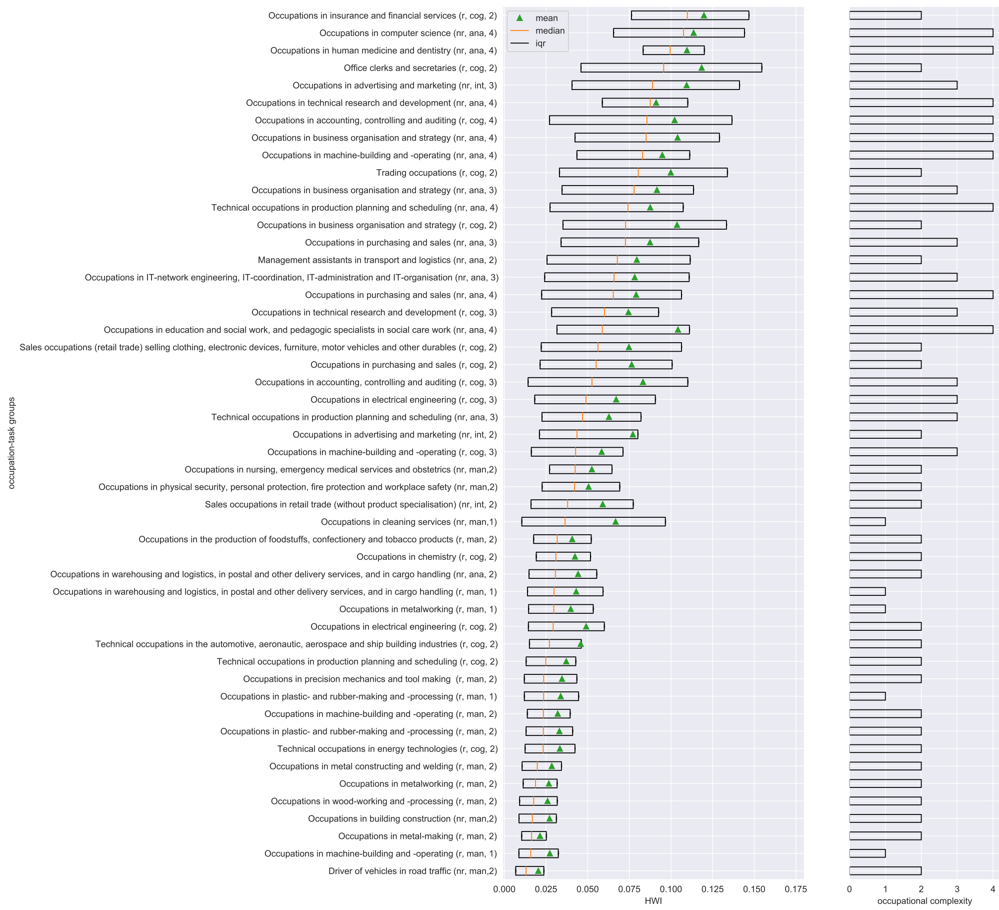
Variable	**Description**
net income to assets$_{firm}$	Ratio of a firm's net income to total assets. Source: Orbis.
cash flow to assets$_{firm}$	Ratio of a firm's cash flow to total assets. Source: Orbis.
log(total assets)	Natural logarithm of a firm's total assets (CPI-adjusted to the base year 2010). Source: Orbis.
leverage	Ratio of a firms' debt to the sum of debt and shareholders' funds. Debt is defined as the sum of loans and long-term debt. Source: Orbis.
tangibility	Ratio of a firm's tangible assets to its total assets. Source: Orbis.
cash holdings	Ratio of a firm's cash holdings to its total assets. Source: Orbis.
listing dummy	Dummy indicating whether the firm is listed on a stock exchange. Source: BeH, BHP, Orbis.

BeH stands for Beschäftigten-Historik provided by the Institute of Employment Research, *BHP* for Betriebshistorik Panel provided by the Institute of Employment Research, *BP* for Betriebspanel provided by the Institute of Employment Research, and *Orbis* for the Orbis database by Bureau van Dijk.

Appendix C

Horizontal wage inequality and occupation-task groups

This figure shows the horizontal wage inequality (HWI) in different occupation-task groups. We limit this analysis to the 50 most common occupation-task groups in our sample; they account for approximately 70% of the employee-years. The occupation-task groups are sorted by the median value of the HWI measure. A detailed description of all variables can be found in Appendix B.



Appendix D

Horizontal wage inequality, occupation-task groups, and task heterogeneity

This figure illustrates the relation between task heterogeneity and the horizontal wage inequality (HWI) in different occupation-task groups. We limit this analysis to the 50 most common occupation-task groups in our sample; they account for approximately 70% of the employee-years. We measure the task heterogeneity of an occupation-task group by the Herfindal index of the fraction of analytical nonroutine tasks, interactive nonroutine tasks, cognitive routine tasks, manual nonroutine tasks, and manual routine tasks. A detailed description of all variables can be found in Appendix B.

(a) HWI **(b)** residual HWI