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Unions, Internationalization, Tasks, Firms, and Worker Characteristics: A Detailed Decomposition Analysis of Rising Wage Inequality in Germany

Martin Biewen[1] · **Matthias Seckler**[1]

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Abstract
This paper provides a comprehensive quantitative assessment of the importance of the factors associated with the rise in male wage inequality in Europe's largest economy over the period 1995-2010. We simultaneously consider an extensive set of explanatory factors including personal characteristics, measures of internationalization, task composition, union coverage, industry, region, and firm characteristics. Our study uses a different data source than most of the other prominent studies on wage inequality in Germany. We carefully assess differences implied by the different data and show that previous studies have most likely underestimated the dominating role of de-unionization for the rise in German wage inequality. As the second most important factor, we identify compositional effects of personal characteristics such as age and education. We find only moderate effects linked to internationalization, firm heterogeneity, task changes and regional convergence.

Keywords De-unionization · Skill-biased technical change · RIF regression

1 Introduction

An extensive literature has documented a steady increase in wage inequality since the early 1980s in many countries around the world (see Katz and Autor 1999, and Acemoglu and Autor 2011 for surveys, and Dustmann et al. 2009, for the German case). Different explanations have been proposed for this trend. The most prominent explanation are changes in

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✉ Martin Biewen
martin.biewen@uni-tuebingen.de

Matthias Seckler
matthias.seckler@uni-tuebingen.de

[1] School of Business and Economics, University of Tübingen, Mohlstr. 36, 72074 Tübingen, Germany

demand and supply across skill groups connected to skill-biased technological change (Katz and Murphy Katz and Murphy, 1999; Juhn et al., 1993; Goldin and Katz 2008, among others). Observing that more recent changes in the US wage distribution were not uniformly favoring higher skills, the basic SBTC hypothesis was refined by the task-based approach (Autor et al. 2003, 2008; Acemoglu and Autor 2011). This more refined version of the SBTC hypothesis explains further inequality increases by falling demand for non-manual routine occupations in the middle of the distribution which fall back when compared to manual routine occupations at the bottom and non-manual analytic occupations at the top of the distribution. At the same time, a number of researchers have criticized the focus on the SBTC hypothesis suggesting that compositional and institutional changes such as de-unionization and changes in the minimum wage account for a substantial part of the inequality increase (DiNardo et al. 1996; Card and DiNardo 2002; Lemieux 2006). The third line of explanation, international trade, was identified as less important in earlier studies (e.g. Katz and Murphy 1992) but has been taken up again as a potentially important factor more recently (Autor et al. 2014; Ebenstein et al. 2014, Firpo et al. 2014). Finally, a number of recent contributions have emphasized the potential role of growing heterogeneity between firms for the rise in wage inequality (e.g., Card et al. 2013; Barth et al. 2016; Baumgarten et al. 2018, and Song et al. 2019).

In order to evaluate these explanations in a more general sense, it is important to look at the relevance of these factors for a range of countries. A particular interesting case is Germany, given its large degree of integration in the world economy and its relative economic importance within the European Union. Adding to previous research on the German wage distribution (Dustmann et al. 2009; Antonczyk et al. 2010; Card et al. 2013, see more detailed literature review below), this paper makes the following contributions. First, we use a different data set than most of the other studies that have examined the German wage distribution. We use data from the mandatory *German Structure of Earnings Surveys (GSES)* conducted by the German Federal Statistical Office, which, compared to the widely used administrative data sets provided by the Institute for Employment Research (IAB), includes information on hourly wages (instead of daily or monthly earnings), is not censored at the social security contributions threshold and contains a richer set of covariates.[1] In particular, our data set includes information on unionization at the individual rather than at the firm level, which makes it different from all other data sets for Germany known to us. We show that this feature makes a substantial difference for the results, suggesting that previous studies have substantially underestimated the strong role de-unionization played for the rise of German wage inequality.

Our second contribution is that we simultaneously consider a very large set of potential explanatory factors for changes in the wage distribution, larger than in previous contributions. Our set of explanatory factors covers all the major explanations for rising wage inequality that have been put forward in the literature including rich information on worker characteristics, firms, union coverage, information on the task composition of occupations as well different measures of internationalization. As in other contexts, considering as many potential factors at the same time as possible is important to rule out spurious findings and to pin down the quantitative importance individual factors. It is very clear that, if important factors of distributional change are omitted from the analysis, then their impact will be

[1]The *LIAB* was used by Dustmann et al. (2009), Card et al. (2013), and Baumgarten et al. (2018), among many others. The only other study using the *GSES* we are aware of is Antonczyk et al. (2010), who use only a subset of the waves considered by us.

spuriously picked up by the factors included. For our econometric analysis, we use a powerful tool for distributional analysis, the RIF regression approach (Firpo et al. 2009, 2018), which is particularly well-suited to control for a large number of explanatory variables. We also address some issues in the empirical implementation of RIF regressions, which may be of interest to researchers who want to apply this method.

To preview our results, we find that the most salient factors behind the recent rise in German wage inequality were a dramatic decline of union coverage and compositional changes of the work force with respect to age and education. These results hold after simultaneously controlling for an extensive list of other determinants of the wage distribution including information on job tasks, firm characteristics, measures of internationalization, regional wage differences and the sector composition of the economy. Using information on individual union coverage, we demonstrate that the use of firm-level information on unionization does not fully capture the substantial effect de-unionization had on the German wage distribution. Our results point to the fact that the mere shrinking of the part of the economy in which wages were more compressed was to a large part responsible for the trend towards increasing wage inequality. As the second most important factor, we identify compositional effects related to personal characteristics, especially workers' age and education. Such effects are consistent with the hypothesis that the increasing demand for higher skills due to SBTC was matched by rising supply for such skills due to educational upgrading and population aging. This follows from the insight that, in the absence of rising demand due to SBTC, rising supply of high skills would have depressed the wage premia for such skills which cannot be observed in the data. We do measure some wage structure effects related to internationalization, firm heterogeneity, task changes, and regional wage convergence, but these were very moderate compared to the dominating effects of de-unionization and compositional changes of the workforce.

The rest of the paper is structured as follows. Section 2 provides a review of some related literature. In Sections 3 and 4, we describe our data and econometric methods. Section 5 presents our empirical results. In Section 6, we discuss these results and provide some conclusions.

2 Literature review

In this section, we provide a selective review of contributions dealing with changes in the German wage structure and with effects of the factors considered by us on the wage structure in other countries. Based on administrative data derived from social security records, Dustmann et al. (2009) analyzed changes in the distribution of daily earnings in West Germany up to 2004. They showed that inequality increases first started in the 1980s at the top, and then in the 1990s at the bottom of the distribution, about a decade later than in the US. Their analysis suggests that compositional effects of personal characteristics account for a substantial part of inequality changes in the upper half of the distribution and nonnegligible shares at the bottom, while compositional changes of de-unionization explain considerable changes at the bottom but only some changes in the upper part of the distribution. Dustmann et al. (2009) consider each of the factors mentioned above separately and do not provide a break-down of the quantitative importance of each factor controlling for all other factors.

Based on a different data base, Antonczyk et al. (2009) examined polarization effects of task changes on the distribution of monthly wages. They find that changes in task assignment reduced rather than increased wage inequality. Antonczyk et al. (2010) used two waves

of the data base we also use in this article in order to study changes in the West German wage distribution and the gender wage gap between 2001 and 2006. Their results suggest that changes in firm-level characteristics other than those related to union bargaining were the most important determinants of rising inequality, while changes in unionization did not have much explanatory power when other firm-level characteristics were controlled for. Antonczyk et al. (2010) use a different methodology and a less extensive set of explanatory variables than we do. Moreover, there were substantial developments in some covariates outside the period 2001 to 2006 (esp. de-unionization), which are not covered by their analysis.

Also using administrative data, Card et al. (2013) studied the effects of fixed person and firm effects on the distribution of daily wages. They conclude that both increasing dispersion in person and in firm effects, as well as increasing assortative matching of high person to high firm fixed effects contributed to increasing wage inequality. Based on linked employer-employee data, Ohlert (2016) studies determinants of establishment heterogeneity in Germany. His study concludes that increasing differences in firm size and workforce composition contributed to rising inequality, while changes in union coverage played no important role. Also based on administrative data but without information on union coverage, Rinawi and Backes-Gellner (2015) examine task-composition effects on the wage structure. At odds with Antonczyk et al. (2009), they find that task effects explain up to one third of the rise in wage inequality. Using the same data, Ehrl (2017) attributes most of the increase in German wage inequality to differences in returns to characteristics and identifies occupation-specific skills as the most important single factor.

In a setup very similar to that used in our study, but based on the administrative data sets used in the other contributions, Baumgarten et al. (2018) aim to disentangle between-plant and within-plant sources of wage inequality in Germany. Similar to what we find in this study, Baumgarten et al. (2018) identify an important role for de-unionization for rising wage inequality in Germany. They also estimate significant effects due to shifts between industries, which we do not find in our study. While the set of firm-level variables in Baumgarten et al. (2018) is more informative than ours, we have access to more detailed information on individual-specific covariates than available in administrative data. In particular, we have information on union coverage at the individual rather than at the firm level. We analyze these differences in more detail below.

There is a small number of articles that empirically address aspects of internationalization for wages in Germany. Schank et al. (2007) and Klein et al. (2013) investigated the exporter wage premium, while Geishecker and Görg (2008) and Baumgarten et al. (2013b) studied wage penalties associated with offshoring. These articles contain useful information on the effects of internationalization on wages but do not provide a full distributional analysis that quantifies the magnitude of these effects on the overall wage distribution. A full distributional analysis of the exporter wage premium is given in Baumgarten (2013a), who finds that these effects are rather small when individual and firm characteristics are controlled for. Baumgarten et al. (2018) also find moderate effects of exporting on the wage structure in Germany.

Our short review of previous contributions on changes in the German wage distribution demonstrates that the literature has not reached a consensus about its main driving forces. As a related article for the US, we would like to point out the study by Firpo et al. (2014) who have analyzed the influence of detailed task measures and measures of offshorability on changes of the US wage distribution. Consistent with Autor et al. (2008), they find that, while distributional change in the 1980s was very monotonic (high quantiles gained, lower quantiles lost), this pattern became U-shaped in the 1990s and 2000s. They further show

that (in contrast to what we find for Germany) recent inequality increases were associated with wage structure rather than composition effects and that offshorability became a more influential factor in the 1990s and 2000s.

3 Data and descriptive statistics

The empirical analysis in this paper uses information from four waves (1995, 2001, 2006, 2010) of the *German Structure of Earnings Surveys (GSES)* provided by the German Federal Statistical Office. The *GSES* are linked employer-employee data, which allow us to to consider a rich set of covariates both at the person and the firm level. We use the minimally anonymized version of the *GSES* which is only accessible onsite at the German Statistical Offices. From a technical point of view, the *GSES* are the result of a two-stage random sample. The first stage represents a draw from all German establishments with at least ten employees subject to social insurance contributions. The second stage is a random draw from all employees working in the selected establishment. We use appropriate sample weights in all our analyses to ensure that our results are representative for the population of firms and workers studied by us. The information in *GSES* is highly reliable due to the fact that firms' participation is compulsory under German law.

Our data differ from the widely used administrative data sets provided by the Institute for Employment Research (IAB) in that they contain information on hourly wages (rather than daily earnings) and that the wage information is not censored at the social security contribution ceiling. Hourly wages more directly reflect the prices paid in the labor market than monthly or daily earnings and are thus better suited to test the theories described in the introduction. Focussing on hourly wages also makes results more comparable to those for the US for which most studies have used hourly wages (e.g., DiNardo et al. 1996; Lemieux 2006; Autor et al. 2008; Firpo et al. 2014). Another advantage is that the GSES include a larger and more reliable set of covariates at the individual level than available in administrative data.

The disadvantages of the *GSES* are that it is not a panel study and that its coverage of the economy was incomplete in the early waves. In order to ensure comparability over time, we have to restrict our analysis to the 24 sectors listed in Table 6. A comparison of our sample with other data sources suggest that our choice of sectors covers around 70 percent of the German economy with an emphasis on the traditionally strong manufacturing sector. In order to assess the implications of this limitation, we have checked in the alternative *SIAB* data (Sample of Integrated Labor Market Biographies) how imposing our sector restrictions influences measured inequality trends. As expected, overall trends are very similar, but imposing our sector restrictions implies somewhat lower inequality levels (because we miss part of the service sector). It turns out that these differences are entirely due to the lower half of the distribution, while numbers for the upper half are practically identical to the ones in the SIAB (see Figs. OA1-OA3 in the online Appendix).

In order to enhance the information content of our data set further, we merge complementary information from two additional data sets, the *LIAB* (for firms' export status) and the *BIBB-IAB* (for occupational task measures) as well as aggregate information provided by the Federal Statistical Office (see next section for more details). Finally, we restrict our sample to prime age (20-60 years) men working full-time (i.e. at least 30 hours per week). In line with the existing literature, we do not include women in the present analysis, given their much lower participation rate in full-time work and given the potential difficulties of sample selection bias.

3.1 Hourly wages

Our hourly wage measure is defined as October earnings including additional payments from overtime and bonuses from shift work, divided by paid working hours in October including overtime. We inflate price levels in 1995, 2001, 2006 to the 2010 level using the German consumer price index (CPI). For reasons of plausibility, we exclude a small number of wage observations with less than 4 euros per hour as well as those associated with a monthly working time of more than 349 hours. Although the wage information in the *GSES* is largely uncensored, a censoring threshold at 25,000 DM (approxmiately 12,782 Euro) applied in 1995. In order to ensure comparability over time, we extend this censoring threshold to all other years adjusting for changes in the price level (for example, the implied censoring point for 2010 amounts to 15.879 Euro). We argue that we are still able to provide a comprehensive picture of the overall distribution of male hourly wages, as this censoring affected only about 200 (approximately 0.03%) of the observations for 1995 and a similar, though slightly increasing number of observations in the other waves (2001: 0.05%, 2006: 0.16%, 2010: 0.18%). Ultimately, our sample selection criteria lead to a total number of 1,923,542 observations used in our analysis (1995: 592,198 employees in 23,668 firms, 2001: 359,495 employees in 15,438 firms, 2006: 533,497 employees in 15,477 firms, 2010: 438,352 employees in 13,285 firms).

3.2 Explanatory factors

Our analysis considers the following explanatory variables which we combine into seven different subgroups representing the different factors whose influence on the wage distribution we study in our decomposition analyses. We label the different subgroups as *Unionization*, *Personal*, *Tasks*, *Internationalization*, *Firm*, *Sector*, *Region*. Descriptive statistics on these variables and their change over time are given in Table 6 in the Appendix.

3.2.1 Unionization

In contrast to other data sets for Germany, our data includes information about union coverage *at the employee level*. This means firms report for each individual separately whether or not a given worker was paid according to some union agreement (in the original data, firms report the id of the exact union agreement used to determine the pay of the employee). This is in contrast to the broader firm-level information available in other data sets for Germany in which one only observes very broadly whether or not the firm takes part in specific forms of union bargaining, but not to what extent the pay of a given employee is determined by a union agreement.

In Germany, there are different variants of union bargaining. *Sectoral bargaining* refers to the case in which unions and employers form an agreement at the sector level. Workers need not be union members in order to be covered by sectoral union agreements. Similary, not all employees of the firm are necessarily paid according to the sectoral agreement. *Firm bargaining* represents the case in which unions and employers reach an agreement at the firm level. Similarly, such an agreement will typically (but not always) also apply to employees in the given firm who are not union members. It is the owners or the management of the firm who decide which bargaining regime to take part in. In particular, firms may decide not to engage in union bargaining, to leave existing agreements, or to deviate from existing agreements for individual workers. This includes the possibility of paying lower wages for new hires than for incumbents after having opted out of existing agreements. There may also

be 'opening clauses' that exempt certain employees from union coverage. For more information on the varieties of union coverage in Germany, see Antonczyk et al. (2010), Brändle et al. (2011), Fitzenberger et al. (2011, 2013), and Dustmann et al. (2014).

It turns out that the distinction between the firm's general coverage status and that of the individual worker is quite significant. In Table 1, we show that union coverage dropped generally, but that a substantial part of this drop was due to the fact that fewer and fewer workers in firms who reported to take part in union bargaining were actually paid according to a union agreement. In addition, even in firms that generally reported not to take part in union bargaining, some 14 percent of workers were paid according to a union agreement in 1995. This proportion dropped to zero by 2010. In general, the drop in the number of individuals paid according to union agreements was massive: from 1995 to 2010, the proportion of uncovered workers increased from 26.5 percent to 61 percent, while that of individuals paid according to sector agreements fell from 69.7 to 35.7 percent. By contrast, the group of individuals covered by firm contracts stayed approximately constant.

3.2.2 Personal characteristics

In this subgroup, we include the individual's age (8 categories), tenure (6 categories), educational qualification (6 categories) and occupational position (3 categories). Note that our education variable is more detailed and more reliable than in the administrative data where it is often missing or unreliable as it is not needed for the administrative purpose (see Fitzenberger et al. 2006). As evident from Table 6, these variables followed some notable trends over the period under consideration. In particular, there was some aging of the German labor force as evident from the declining population shares of age groups below 40 years and the rising shares of those above 40 years. We observe a slightly rising share of higher tenure groups at the expense of the lowest tenure bracket (0-5 years). There was also considerable educational upgrading which is reflected in the declining share of individuals with lower/middle secondary schooling with or without vocational training, and the rising share of individuals with an upper secondary degree (with or without vocational training) and with tertiary education. Finally, there was a compositional shift from skilled blue collar work to white collar work, while non-skilled blue collar work stayed constant or even increased slightly.

3.2.3 Tasks

For modeling occupational tasks, we exploit the information in the commonly used *German Qualification and Career Survey of Employees (BIBB-IAB)*, jointly provided by the Federal Institute for Vocational Training (BIBB) and the Institute for Employment Research (IAB). These data allow us to construct measures for the analytical, interactive and manual task content of individuals' jobs. More precisely, we use three independent cross sections, each covering 20,000-30,000 individuals from the years 1998/99, 2006 and 2012, which come closest to our sample period. Given some inconsistencies in how the task questions were asked in these surveys over time, we follow the common practice in the literature and consider time-constant task measures per occupation (Baumgarten et al. 2013b; Firpo et al. 2014; Böhm et al. 2016). In order to make the task information independent of time, we pool the information from all the three surveys.

Table 7 in the Appendix documents the mapping of the different activities into the three task-groups, i.e. *analytical*, *manual* and *interactive*. In doing so, we closely follow Gathmann and Schönberg (2010). The share of a certain task-group g is defined as the number

Table 1 Development of unionization (individual- vs. firm-level information)

		Unionization (individual level)											
		No coverage				Sectoral coverage				Firm coverage			
		1995	2001	2006	2010	1995	2001	2006	2010	1995	2001	2006	2010
Unionization (firm level)	No coverage	86.40	89.81	97.16	99.80	13.14	9.55	2.50	0.19	0.45	0.64	0.34	0.01
	Sectoral coverage	8.32	12.05	20.95	24.20	91.65	87.83	78.79	75.46	0.03	0.12	0.26	0.34
	Firm coverage	12.02	13.75	19.46	24.15	11.92	7.17	1.01	1.66	76.06	79.08	79.53	74.20
	Total	26.50	38.80	55.01	61.00	69.70	56.91	40.91	35.72	3.79	4.29	4.08	3.28

Source: Structure of Earnings Surveys 1995, 2001, 2006, 2010 and own calculations

Relative frequencies are reported within rows of each cell

of activities in group g performed by an individual i divided by the total number of tasks performed by the same individual, i.e.

$$Task_{ig} = \frac{number\ of\ activities\ in\ group\ g\ performed\ by\ i}{total\ number\ of\ activities\ in\ all\ groups\ performed\ by\ i}. \quad (1)$$

As common in the task literature (e.g. Spitz-Oener 2006), these shares are first calculated at the person-level and then averaged at the level of 2-digit occupations. In Fig. OA4 in the online Appendix, we document that the share of analytical and interactive tasks increased over the period 1995-2001, while that of manual tasks decreased.

3.2.4 Internationalization

This group of covariates is intended to represent three different aspects of internationalization: the exporting behavior of firms on the one hand, and the pressure on 2-digit occupations exerted by offshoring and import competition on the other. As the *GSES* data lack a firm-level variable on export behavior, we impute this information from the *LIAB* using an ordered logit model for the categories *No Exports*, *Export share 1-25%*, *Export share 26-50%* and *Export share 51-100%*, where export share represents exports in total sales. For this imputation, we exploit a large number of individual and firm characteristics that are available in both data sets in order to predict the export share category for each observation in the *GSES*.[2] Our predicted export share variable displays very similar patterns as in the original *LIAB* data. As shown in the summary statistics in Table 6, we observe a steeply increasing trend for the share of the predicted *Export share 51-100%* category at the expense of the lower categories, which was partly reversed after the financial crisis in 2008. By contrast, the share of observations in the *No Exports* category stayed relatively constant with minor fluctuations.

In addition, we use information from the German national accounts (Federal Statistical Office of Germany 1999) at the 2-digit industry level in order to derive measures of wage pressure on occupations due to offshoring and imports of consumer goods. We differentiate between 77 occupations and 24 industries.[3] Following Baumgarten et al. (2013b) and Ebenstein et al. (2014), we first consider the share of intermediate input imports coming from the same industry abroad as an indicator for offshoring at the industry level. In order to arrive at a measure reflecting the wage pressure on occupation k due to trends in offshoring activities across industries, we compute the average of these offshoring intensities across all industries in which workers with occupation k work (using the employment shares of occupation k in industry j as weights). Consequently, our measure of wage pressure on the 2-digit occupation k in year t due to offshoring is given by

$$Offs_{kt} = \sum_{j=1}^{J} \frac{L_{kjt}}{L_{kt}} Offs_{jt} \quad (2)$$

where $Offs_{jt}$ denotes the industry-level offshoring intensities and $\frac{L_{kjt}}{L_{kt}}$ is the employment share of occupation k in industry j in year t.

[2]Our model includes education (7 categories), a polynomial in age and tenure, occupational status (4 categories), sector (20 categories), and firm size (7 categories).

[3]The data include the *Classification of Occupations (KldB)* at the 2-digit level, i.e. *KldB75* in 1995 and 2001, *KldB88* in 2006 and 2010. For reasons of time consistency minor aggregations were required leading to a total number of 77 occupations. At the industry level, we consider the 24 sectors of the economy listed in Table 6, see next section for more details.

For imports of consumer goods, we proceed analogously. Let $Imports_{jt}$ be the share of imports of consumer goods in industry j in year t. Our measure of wage pressure on occupation k in year t due to imports of consumption goods in the sectors this occupation is employed in is then defined as

$$Imports_{kt} = \sum_{j=1}^{J} \frac{L_{kjt}}{L_{kt}} Imports_{jt}. \tag{3}$$

3.2.5 Firms, sector, region

Under the label *Firm* we include information on firmsize (7 categories) and information on whether corporate management is influenced by the state. The distribution of these characteristics was relatively stable over the period 1995 to 2010 (see Table 6). In order to address changes in the composition of the economy over time and changes in inter-industry wage differentials, we include under the label *Sector* categorial dummies for 24 different sectors of the economy based on the *German Classification of Economic Activities (WZ)*, which we harmonized over time.[4] There were generally no big shifts in the sectoral composition between 1995 and 2010. Notable exceptions were a sizable decline of the construction sector and a moderate growth of wholesale trade (Table 6). Finally, we include information on the federal state in which a person worked under the label *Region* (16 categories). Including this information is potentially important as there are sizable differences in mean wages paid in different federal states, especially if one compares East and West German states.

4 Econometric methods

In order to study the quantitative importance of the different sets of covariates on the changes of the wage distribution over the period 1995 to 2010, we apply RIF-regressions (Firpo et al. 2009, 2018). The *Recentered-Influence-Function (RIF)* decomposition is based on the recentered influence function defined as $RIF(y, \nu) = \nu + IF(y; \nu)$ which integrates to the statistic of interest $\nu(F_y) = \int RIF(y; \nu)\, dF(y) = E(RIF(y; \nu))$, where F_y is the distribution function of the dependent variable (log hourly wage in our case). In the simplest form, the RIF is modeled as a linear function of the explanatory variables, i.e. $E[RIF(Y; \nu)|X] = X\gamma$, where γ can be estimated by means of simple OLS. The statistic of interest is then obtained as $\nu(F_y) = E(E[RIF(Y; \nu)|X]) = E(X)\gamma$, using the sample counterparts estimated by OLS (i.e. $\hat{\nu} = \bar{X}\hat{\gamma}$).

As shown in Firpo et al. (2009), the coefficients γ of the RIF regression represent the effects of marginal shifts in the distribution of the components of $X = (X_1, \ldots, X_k)$ on the statistic of interest. For example, if $\nu(F_y)$ is an unconditional quantile of y and X_j union coverage status, then γ_j will reflect how much quantile $\nu(F_y)$ of the unconditional distribution of wages y is increased or decreased if the share of unionized workers is marginally increased. The RIF regression follows the classic division into 'composition' and 'wage structure' effects. It uses the idea that the distribution of wages will change whenever the

[4] Our sector classification is derived from the 2-digit *German Classification of Economic Activities (WZ)*. The *German Classification of Economic Activities (WZ)* changed between the waves of 1995, 2001 (WZ93) and 2006 (WZ03) as well as 2010 (WZ08). While the change from WZ93 and WZ03 should not affect our results at the 2-digit level, we acknowledge that the latter change might give rise to minor inconsistencies for the period 2006-2010.

composition of the workforce changes, even if wages paid for given characteristics stay constant ('composition effect'). On the other hand, it may change if the composition of the workforce stays constant, but wages paid for given characteristics change ('wage structure' effect). We will use this method to carry out detailed decomposition analyses for different inequality measures $\nu\left(F_y\right)$ based on quantiles, such as the 85-15, 85-50 and 50-15 log wage gap, the Gini coefficient and the variance of log wages.

Specifically, we use a refinement of this method suggested by Firpo et al. (2014, 2018), i.e. the RIF decomposition is combined with the semi-parametric reweighting approach introduced by DiNardo et al. (1996). This is done to avoid bias in case the linear specification for the RIFs described above is not sufficiently precise, as the linear specification is only valid locally. The basic idea underlying this approach is to create an artificial time period 01, in which the distribution of X in period 0 is reweighted to that of period 1. Using these three periods, two separate Oaxaca-Blinder decompositions are run on the recentered influence function, leading to

$$\Delta_O^\nu = \underbrace{\left(\bar{X}_{01} - \bar{X}_0\right)\hat{\gamma}_0^\nu}_{\Delta_{X,p}^\nu} + \underbrace{\bar{X_{01}}\left(\hat{\gamma}_{01}^\nu - \hat{\gamma}_0^\nu\right)}_{\Delta_{X,c}^\nu} + \underbrace{\bar{X}_1\left(\hat{\gamma}_1^\nu - \hat{\gamma}_{01}^\nu\right)}_{\Delta_{S,p}^\nu} + \underbrace{\left(\bar{X}_1 - \bar{X}_{01}\right)\hat{\gamma}_{01}^\nu}_{\Delta_{S,c}^\nu}. \quad (4)$$

In this equation, the detailed composition effects $\Delta_{X,p}^\nu$ reflect the contribution of changes in the distribution of particular covariates (or groups of covariates) to the overall change of the distributional statistic. For example, suppose that there are wage differentials *between* sectors covered and those not covered by unions in the sense that union coverage is associated with nonnegative wage premia.[5] In addition, it may be the case that inequality *within* the sectors covered by unions differs from inequality in sectors not covered (e.g., unions compress wages in the sectors covered by them). Now assume that union coverage in the economy declines. The overall compositional effect of this decline on wage inequality may be positive or negative depending on whether the decrease in inequality between sectors dominates the increase in inequality due to the declining share of sectors with low levels of within-inequality. The specification error $\Delta_{X,c}^\nu$ in Eq. 4 reflects the differences in estimated RIF coefficients in the sample of period 0 and the coefficients estimated in the sample of period 0 whose distribution was reweighted to that of period 1.

The wage structure effect $\Delta_{S,p}^\nu$ represents the contributions of changes in the effects γ individual covariates (or groups of covariates) have on the distribution of wages. This includes effects on pay inequality *between* and *within* subgroups. In the above example, this would include changes in the magnitude of wage differentials *between* sectors covered and those not covered by unions, as well as changes in the amount of wage compression *within* sectors resulting from changes in union policies (e.g., unions might increase or loose their ability to compress wages). Finally, the reweighting error $\Delta_{S,c}^\nu$ reflects differences in the means of covariates in sample period 1 and those in sample period 0 whose distribution was reweighted to that of sample period 1. The reweighting error will be close to zero if reweighting is successful in changing the distribution of covariates in sample period 0 to that of sample period 1.

To our best knowledge, the RIF-OLS decomposition is the only method known that is capable of providing a detailed, path-independent decomposition of arbitrary distributional statistics into composition and wage structure effects. Other decomposition methods are either confined to particular distributional statistics (e.g. based on variance decompositions,

[5]The following discussion closely follows Firpo et al. (2009).

Juhn et al. 1993), provide no detailed decomposition results (Machado and Mata 2005; Melly 2005; Chernozhukov et al. 2013), or provide detailed decomposition results that depend on some ordering of factors (DiNardo et al. 1996; Antonczyk et al. 2010). For more details, see the general discussion in Fortin et al. (2011).

As described in the literature, detailed decompositions of wage structure effects for a set of categorical variables depend on the choice of the omitted reference group (Fortin et al. 2011). This also applies to the RIF decomposition described above. In preliminary estimations, we found that the detailed wage structure effects estimated by us sometimes considerably depended on which reference groups for the various sets of our categorial variables we chose. This is not surprising as the intercept of a regression always represents the average outcome for a very specific reference individual (i.e. an individual with the base level of education, age, tenure, sector, firmsize, region etc.). The intercept of the regression (and hence the exact value of all other regression coefficients) will therefore depend to a large extent on how the position of the reference individual changes over time. In order to make our regression results independent of the choice of the reference individual, we normalize the RIF regression coefficients within sets of categorial variables such that they sum up to zero, i.e. $\sum_{j \in J} \gamma_j = 0$, where J is a set of categorial dummy variables summing up to one (e.g. age categories). Gardeazabal and Ugidos (2004) discuss this kind of normalization for the case of the standard Oaxaca-Blinder decomposition. An advantage of the normalization is that it only shifts the intercept of the regression, leaving the relative differences between coefficients intact.

Applying this normalization will not only make results independent of the choice of a reference group but will also facilitate the general interpretation of RIF decomposition results. Given that the RIF regression coefficients for groups of categorial variables are normalized to sum up to zero, information about the general level of the statistic modeled by the RIF regression (e.g. a quantile) will be shifted to the intercept of the regression, while differences in regression coefficients will only reflect deviations of individual categories from this general level.[6] The intercept of the RIF regression will therefore capture general changes in unconditional quantiles (or other inequality measures) that are not related to pure relative changes within groups of categorial variables and which therefore cannot be attributed in a detailed way to individual regressors. They may still reflect changes in the relative importance of groups of categorial variables (e.g. the importance of age vs. education effects), but such changes cannot be attributed to individual variables or groups of variables. They should therefore be summarized in the intercept as a general contribution to wage structure effects. Finally, changes in the intercept will also incorporate general changes in unconditional quantiles (or other inequality measures) that are due to factors not included as observables in the analysis.

It is important to point out that RIF decomposition (as most other statistical decomposition techniques) ignores general equilibrium effects. It correspond to the hypothetical thought experiment of changing the distributions of observed covariates without changing the wage structure (see Fortin et al. 2011, for a more detailed discussion). Similarly, we emphasize that the RIF decomposition results should certainly not be interpreted as causal effects. However, they do represent a rich and informative description of how distributional change is related to changes in observables. Even if these relationships are not causal, it is important to identify variables through which distributional change is mediated, or with which it is correlated.

[6] We illustrate this kind of normalization for the case of a mean regression below.

5 Empirical results

5.1 Development of inequality

The general development of the distribution of real hourly wages between 1995 and 2010 is displayed in Fig. 1. For the period as a whole, quantiles near or above the median gained whereas quantiles below the median lost. This general trend is confirmed by the results for the Gini coefficient and the variance of log wages. The results for the 50th to 15th percentile and the 85th to 15th percentile in Fig. 2 suggest that the inequality increases were steeper in the lower than in the upper part of the distribution, except at the very end of the observation period.

As to the top of the distribution, there were only moderate inequality increases between the 95th and the 90th percentile but more pronounced increases between the 99th and the 95th percentile. Although our data excludes developments at the very top of the distribution of hourly wages, our findings are consistent with the view that changes in the upper part of the German wage distribution were relatively modest when compared to other, especially Anglo-Saxon countries (see Atkinson et al. 2011; Piketty and Saez 2014; Bartels and Jenderny 2015).

5.2 Trends in between-group inequality

In order to prepare the distributional RIF-analysis presented below, we first examine trends in the relationship between observed characteristics and hourly wages as measured by OLS regressions of log hourly wages on our long list of covariates (Table 2). This regression represents trends in between-group inequality, i.e. in average wage differentials between narrowly defined cells of workers with identical observed characteristics. In order to facilitate interpretation, we apply the normalization described above, i.e. we center estimated

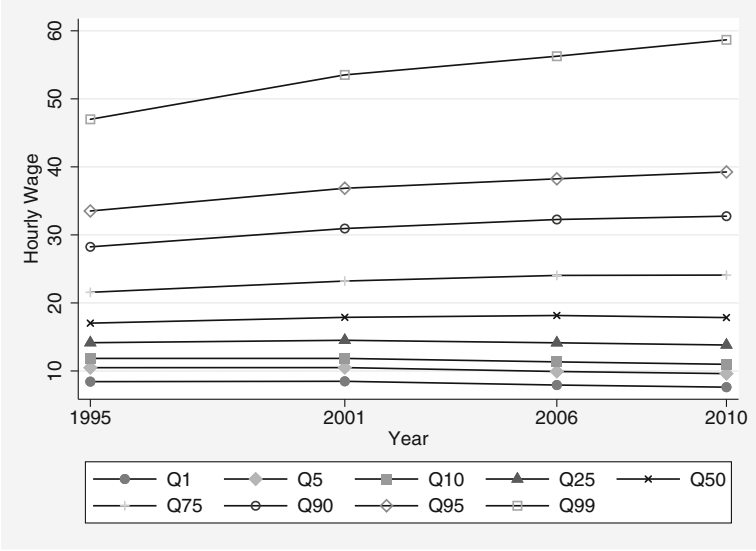

Fig. 1 Quantiles of real hourly wage, 1995-2010

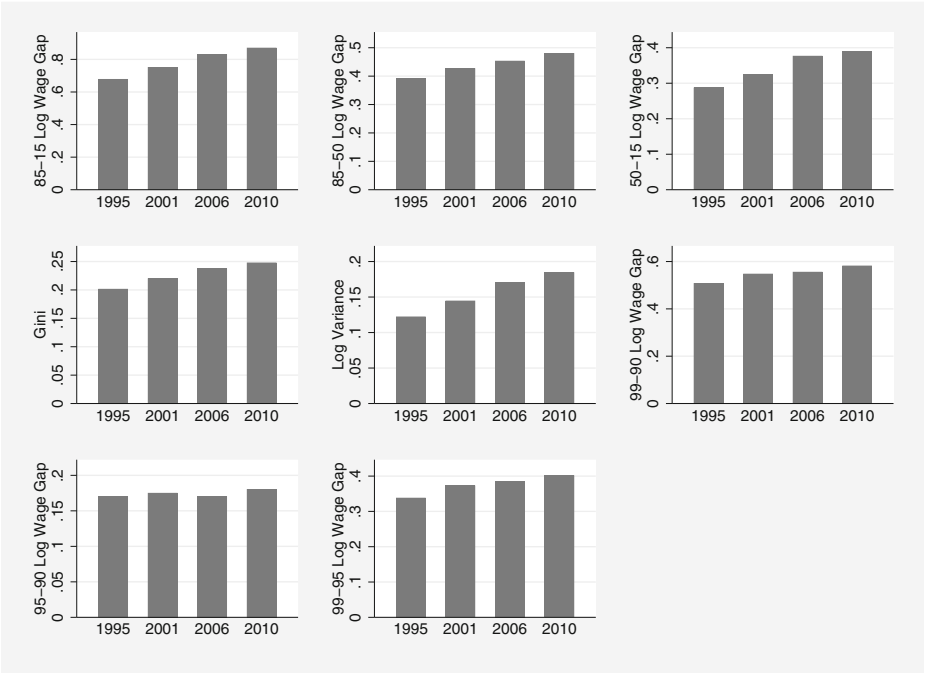

Fig. 2 Development of inequality, 1995-2010

coefficients around zero within groups of categorial regressors. This will provide wage differentials with respect to a mean level of returns normalized to zero.[7]

We briefly summarize the effects of the different covariates. In general, there was a general trend towards widening wage differentials between worker subgroups, reflected in the rising variance of OLS coefficients within subgroups of regressors (e.g. age). We observe a moderate widening of the returns to age, tenure, education and occupational position. The association of wages with offshoring was positive, i.e. occupations that were more affected by offshoring in the different sectors of the economy did not suffer but gain from these activities. On the other hand, we obtain a slightly negative effect of imports in consumption goods on the wages of occupations employed in the respective sectors, suggesting an import pressure effect. There were no changes of these wage differentials over time. By contrast, the exporter wage premium substantially increased over time.[8] Wage differentials across sectors moderately widened over our observation period. As regards the returns to firm size, we observe that the premia at very large firms increased, while those of medium-sized firms tended to fall. There was considerable convergence of wages across federal states

[7]For example, the estimated coefficients for the age categories indicate that in 1995, being in the age group 20 to 25 years was associated with a wage penalty of 13.6 percentage points compared to the mean level of returns to age, while individuals between 51 and 55 years received a premium of 5.4 percentage points above this mean level.

[8]Note the plausible magnitude and high statistical precision of the estimated coefficients for our variables based on external imputations. This proves that our imputation introduces additional information into our data which turns out as highly significant effects in our regressions.

(the variance of the regional coefficients dropped from 2.700 to 1.728). For the different task inputs, we observe a stable positive relative return for analytical tasks, while the return to interactive tasks increased at the expense of that to manual tasks. Note that these task premia and all other coefficients represent ceteris paribus effects holding constant education and a long list of further covariates.

There are interesting trends in wage differentials between workers covered and those not covered by union bargaining (last rows of Table 2). Over the period under consideration, we observe a continuous trend of a deteriorating position of uncovered workers relative to covered workers. In 1995, not being covered by some union agreement was associated with a slightly higher pay than if the person was covered by a pay scheme negotiated by unions. This relationship was reversed from the mid 2000s onwards. Our interpretation of this pattern is that in the years 1995 and 2001, i.e. when union coverage was generally very high, individual non-coverage was mainly used to pay higher wages to highly productive workers. Towards the end of the observation period however, employers more and more used either individual or collective non-coverage in order to limit or even reduce the wages of uncovered workers.

Given the important role unions play in the German labor market, we also carried out the above wage regressions separately for individuals covered and those not covered by union agreements (Tables OA1 and OA2 in the online Appendix). The results confirm the expectation that unions considerably compressed wage differentials across practically all observable covariates (reflected in the much lower variances of regression coefficients for the different sets of covariates) and within narrowly defined groups of workers with identical observable characteristics (as reflected in a lower estimate for the residual variance of the regression). It is especially these strong differences in inequality between covered and uncovered workers that suggest potentially important composition effects as a result of the secular decline in union coverage identified in the previous section (i.e. overall inequality will increase if the more compressed part of the economy shrinks).

5.3 RIF decomposition

Given the local nature of the RIF methodology, our strategy is to apply RIF decompositions separately to our three subperiods 1995-2001, 2001-2006, 2006-2010, and to aggregate (i.e. add up) the contributions of the different factors over the subperiods.[9] We start with a graphical analysis of the effects changes of our covariates have on unconditional quantiles. Figure 3 shows that the change of the distribution of log hourly wages between 1995 and 2010 was such that unconditional quantiles below the 35th percentile fell, while those above the 35th increased. This pattern is distinctively different from the changes in the US wage distribution over similar periods which featured a U-shaped pattern, i.e. especially middle quantiles lost in comparative terms, while lower and upper quantiles gained (Autor et al. 2008; Firpo et al. 2014).

[9]The RIF-regression approximates the effects of marginal changes in the distribution of covariates on inequality measures. The approximation error will be the larger the bigger changes in the distribution of covariates are. In order to keep approximation errors small, it is therefore best to consider changes in covariates over the smallest subperiods available. In a previous version of this paper, Biewen and Seckler (2017), we report more details on individual subperiods. For our estimates, we provide bootstrapped standard errors based on 100 resamples. The resamples are a simultaneous draw from all four years and take account of the clustering at the firm level.

Table 2 OLS regressions of log hourly wage on covariates

	1995		2001		2006		2010	
	Coeff.	Std.	Coeff.	Std	Coeff.	Std	Coeff.	Std
Age 20-25	−0.136	0.002	−0.162	0.003	−0.184	0.004	−0.173	0.004
Age 26-30	−0.058	0.001	−0.072	0.002	−0.099	0.003	−0.093	0.003
Age 31-35	−0.006	0.001	−0.005	0.002	−0.016	0.002	−0.022	0.002
Age 36-40	0.021	0.001	0.031	0.001	0.04	0.002	0.033	0.002
Age 41-45	0.035	0.001	0.041	0.002	0.065	0.002	0.070	0.002
Age 46-50	0.045	0.001	0.047	0.002	0.064	0.002	0.073	0.002
Age 51-55	0.054	0.002	0.056	0.002	0.066	0.002	0.061	0.002
Age 56-60	0.046	0.002	0.062	0.003	0.063	0.003	0.051	0.003
Variance age coefficients (x100)	0.383		0.541		0.777		0.709	
Tenure 0-5	−0.069	0.002	−0.078	0.002	−0.086	0.003	−0.093	0.003
Tenure 6-10	−0.006	0.001	−0.020	0.003	−0.023	0.002	−0.021	0.002
Tenure 11-15	0.010	0.001	0.005	0.002	0.009	0.002	0.007	0.003
Tenure 16-20	0.010	0.001	0.028	0.002	0.025	0.002	0.021	0.002
Tenure 21-25	0.021	0.001	0.029	0.002	0.039	0.003	0.036	0.002
Tenure >25	0.034	0.002	0.035	0.003	0.036	0.003	0.049	0.003
Variance tenure coefficients (x100)	0.110		0.156		0.191		0.221	
Lower/middle secondary without vocational training	−0.109	0.003	−0.129	0.003	−0.130	0.004	−0.140	0.004
Lower/middle secondary with vocational training	−0.061	0.002	−0.073	0.003	−0.079	0.003	−0.091	0.003
Upper secondary (German high school equivalent)	−0.017	0.004	−0.013	0.005	−0.017	0.005	−0.009	0.006
University of Applied Science (Fachhochschule)	0.092	0.003	0.101	0.004	0.099	0.005	0.105	0.004
University	0.169	0.004	0.202	0.005	0.210	0.006	0.224	0.005
Missing information	−0.074	0.005	−0.088	0.007	−0.083	0.009	−0.090	0.006

Table 2 (continued)

	1995		2001		2006		2010	
	Coeff.	Std.	Coeff.	Std	Coeff.	Std	Coeff.	Std
Variance education coefficients (x100)	0.973		1.348		1.404		1.621	
Non-skilled blue collar	−0.106	0.002	−0.099	0.003	−0.107	0.004	−0.117	0.003
Skilled blue collar and foremen	−0.008	0.001	−0.018	0.002	−0.014	0.003	−0.003	0.003
White collar	0.114	0.002	0.117	0.003	0.121	0.004	0.119	0.004
Variance occupational position coefficients	0.809		0.794		0.876		0.929	
Offshoring (0-100%)	0.005	0.001	0.006	0.001	0.008	0.001	0.011	0.001
Imports of consumption goods (0-100%)	−0.002	0.000	−0.002	0.000	−0.002	0.000	−0.002	0.000
No Exports	−0.028	0.004	−0.028	0.005	−0.036	0.006	−0.045	0.007
Export share 1-25%	−0.008	0.002	0.001	0.003	0.003	0.006	−0.021	0.004
Export share 26-50%	0.009	0.003	0.017	0.004	0.004	0.005	0.023	0.005
Export share 51-100%	0.027	0.003	0.010	0.005	0.029	0.005	0.043	0.007
Variance export coefficients (x100)	0.041		0.029		0.054		0.121	
Mining and other quarring	−0.058	0.013	−0.118	0.051	−0.006	0.019	0.047	0.029
Food products, beverages, tobacco	−0.047	0.005	−0.071	0.008	−0.081	0.009	−0.044	0.011
Textiles	−0.086	0.008	−0.073	0.016	−0.081	0.012	−0.124	0.017
Wood	−0.026	0.008	−0.041	0.012	−0.070	0.011	−0.090	0.010
Paper	−0.006	0.008	0.012	0.008	0.030	0.011	0.030	0.009
Printing	0.144	0.007	0.130	0.009	0.123	0.009	0.078	0.013
Coke and petroleum products	0.099	0.025	0.146	0.021	0.171	0.021	0.220	0.056
Chemicals	0.038	0.006	0.033	0.007	0.041	0.008	0.036	0.009
Rubber, plastic	−0.025	0.006	−0.036	0.007	−0.047	0.011	−0.035	0.010
Non-metallic products	0.001	0.005	−0.017	0.006	−0.034	0.010	−0.018	0.013
Basic metals	0.040	0.007	0.054	0.013	0.042	0.013	0.038	0.011

Table 2 (continued)

	1995		2001		2006		2010	
	Coeff.	Std.	Coeff.	Std	Coeff.	Std	Coeff.	Std
Fabricated metal products	0.018	0.005	−0.011	0.007	−0.009	0.009	−0.026	0.011
Computer, electronic, optical products	−0.002	0.006	−0.004	0.008	0.007	0.007	0.008	0.010
Electrical equipment	0.002	0.006	0.000	0.008	−0.014	0.010	−0.005	0.010
Machinery and equipment	0.011	0.005	0.012	0.006	−0.002	0.009	−0.006	0.011
Motor vehicles, trailers	0.115	0.008	0.098	0.009	0.091	0.010	0.077	0.009
Other transport equipment	0.005	0.008	0.071	0.026	0.018	0.013	0.090	0.012
Furniture etc	-0.024	0.008	−0.048	0.011	−0.083	0.012	−0.035	0.008
Electricity, water, recycling	0.084	0.008	0.110	0.011	0.114	0.015	0.073	0.012
Construction	0.058	0.004	0.018	0.005	0.014	0.006	0.017	0.008
Trade of vehicles	−0.040	0.015	−0.037	0.007	−0.032	0.008	−0.076	0.015
Wholesale trade	−0.078	0.007	−0.062	0.009	−0.018	0.009	−0.037	0.010
Retail trade	−0.161	0.008	−0.141	0.012	−0.175	0.024	−0.243	0.015
Finance and insurance	−0.060	0.007	−0.023	0.012	0.001	0.010	0.025	0.013
Variance sector coefficients (x100)	0.457		0.522		0.546		0.732	
Firmsize 10-19	−0.076	0.004	−0.077	0.005	−0.089	0.006	−0.067	0.007
Firmsize 20-49	-0.051	0.004	−0.062	0.004	−0.065	0.006	−0.056	0.006
Firmsize 50-99	-0.035	0.004	−0.035	0.004	−0.041	0.005	−0.031	0.006
Firmsize 100-199	−0.005	0.003	−0.001	0.005	−0.014	0.005	−0.010	0.007
Firmsize 200-499	0.031	0.003	0.025	0.004	0.023	0.006	0.015	0.007
Firmsize 500-999	0.057	0.003	0.065	0.006	0.081	0.011	0.046	0.007
Firmsize >1000	0.078	0.004	0.086	0.006	0.104	0.006	0.103	0.007
Variance firmsize coefficients (x100)	0.285		0.332		0.456		0.309	
State-owned	−0.021	0.004	−0.044	0.008	−0.027	0.007	−0.026	0.006

Table 2 (continued)

	1995		2001		2006		2010	
	Coeff.	Std.	Coeff.	Std	Coeff.	Std	Coeff.	Std
Schleswig-Holstein	0.100	0.006	0.079	0.008	0.061	0.008	0.068	0.011
Hamburg	0.175	0.007	0.191	0.021	0.151	0.011	0.154	0.014
Lower Saxony	0.082	0.005	0.084	0.005	0.050	0.007	0.039	0.007
Bremen	0.136	0.011	0.054	0.012	0.071	0.010	0.083	0.017
North Rhine-Westphalia	0.128	0.004	0.116	0.005	0.095	0.006	0.097	0.006
Hesse	0.106	0.004	0.127	0.007	0.122	0.007	0.106	0.008
Rhineland-Palatinate	0.096	0.006	0.089	0.006	0.08	0.009	0.080	0.007
Baden-Wuerttemberg	0.139	0.003	0.142	0.005	0.148	0.005	0.132	0.007
Bavaria	0.103	0.004	0.098	0.005	0.099	0.007	0.098	0.007
Saarland	0.073	0.008	0.084	0.012	0.068	0.011	0.064	0.011
Berlin	0.058	0.008	0.032	0.009	0.006	0.013	0.022	0.014
Brandenburg	−0.190	0.010	−0.178	0.009	−0.157	0.010	−0.157	0.013
Mecklenburg-West Pomerania	−0.221	0.009	−0.214	0.010	−0.189	0.010	−0.190	0.013
Saxony	−0.267	0.007	−0.249	0.009	−0.22	0.010	−0.219	0.011
Saxony-Anhalt	−0.239	0.008	−0.227	0.009	−0.191	0.010	−0.163	0.012
Thuringia	−0.278	0.009	−0.229	0.008	−0.195	0.010	−0.214	0.010
Variance federal states (16 categories) Coefficients (x100)	2.700		2.322		1.775		1.728	
Share of analytical tasks	0.114	0.012	0.106	0.014	0.120	0.025	0.106	0.018
Share of interactive tasks	0.110	0.012	0.112	0.017	0.111	0.027	0.159	0.021
Share of manual tasks	−0.224	0.005	−0.218	0.007	−0.231	0.007	−0.266	0.009
Variance task coefficients (x100)	2.510		2.377		2.669		3.576	
No union coverage	0.033	0.003	0.021	0.005	−0.009	0.005	−0.019	0.005
Sectoral bargaining	−0.016	0.003	−0.012	0.004	−0.012	0.005	−0.006	0.005

Table 2 (continued)

	1995		2001		2006		2010	
	Coeff.	Std.	Coeff.	Std	Coeff.	Std	Coeff.	Std
Firm bargaining	−0.017	0.005	−0.010	0.008	0.021	0.009	0.025	0.009
Variance unionization coefficients (x100)	0.054		0.023		0.022		0.034	
Constant	2.901	0.005	2.92	0.009	2.931	0.009	2.964	0.009
Root MSE	0.220		0.246		0.267		0.276	
R^2	0.607		0.583		0.582		0.588	

Source: Structure of Earnings Surveys 1995, 2001, 2006, 2010 and own calculations. Standard errors clustered at establishment level

Coefficients within groups of categorial regressors are centered around zero

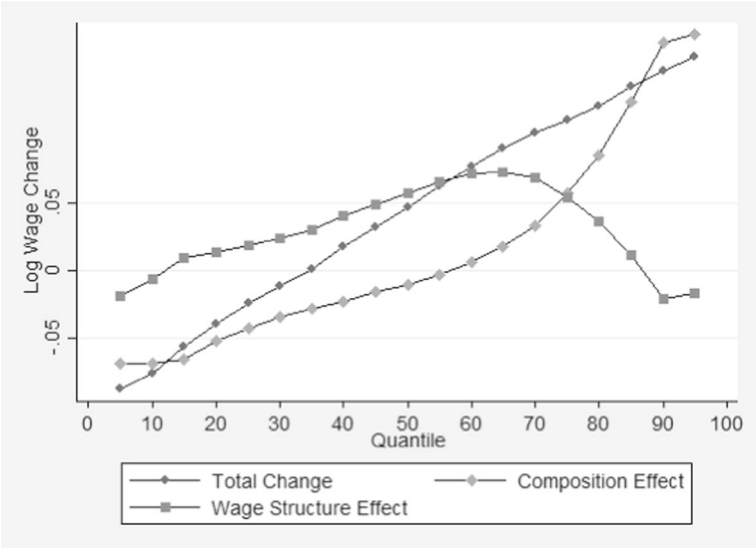

Fig. 3 Aggregate decomposition 1995-2010

Decomposing the overall change into composition and wage structure effects, we find that the pattern of composition effects shows the same monotonic behavior as the overall change, but that additional wage structure effects played some role in the upper middle range of the distribution. In the detailed plot of individual composition effects (Fig. 4), the most striking effect is that of de-unionization. The shrinking share of workers paid according to union pay schedules both substantially depressed quantiles at the lower end of the

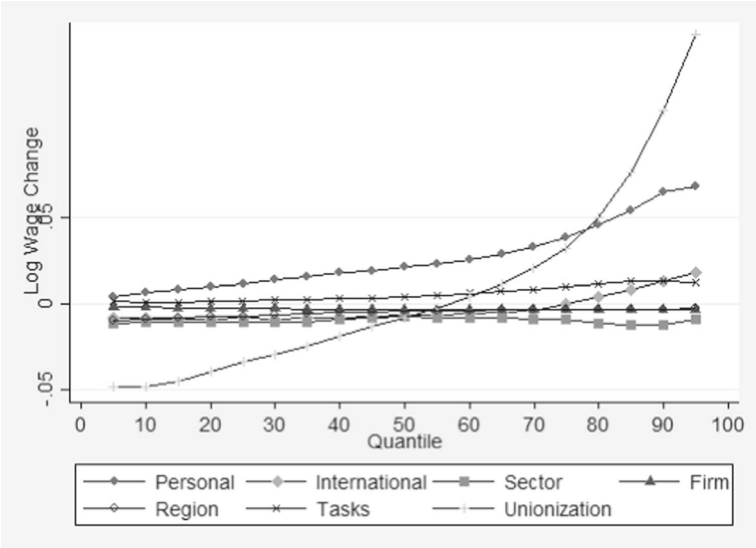

Fig. 4 Composition effects 1995-2010

distribution and lifted quantiles at the upper end. These effects were so strong that they have the potential to account for much of the overall inequality change. Second to effects of de-unionization, compositional effects of changes in personal characteristics also played an important role. This was particularly true for quantiles in the upper half of the distribution of hourly wages, which significantly gained. This result is consistent with the population aging and educational upgrading described in the previous section. The composition effects of all other groups of covariates were relatively modest, although we observe some increases in unconditional quantiles in the upper quarter of the distribution associated with internationalization, and very modest changes in the upper half of the distribution related to task compositions.

Figure 5 provides the break-down of wage structure effects that are related to the different groups of covariates considered by us. These effects are less smooth than the composition effects, and some of them counteract each other. In particular, wage structure effects related to firm characteristics and internationalization tended to favor higher quantiles, while those related to region, unionization and personal characteristics were detrimental for higher quantiles. For tasks, we observe small effects whose patterns are consistent with the polarization hypothesis, i.e. the middle of the distribution lost compared to the bottom and the top of the distribution. Importantly, all of these effects were dominated by general wage structure effects represented by the constant of the RIF regression. As discussed above, the regression constant represents changes in the wage structure that cannot be attributed to particular groups of covariates or that may be related to factors not included as covariates in the analysis. According to Fig. 5, these general wage structure effects were such that the upper middle part of the distribution gained, while the very top part suffered losses.

In Table 3, we provide a detailed break-down of the importance of the different factors for the overall change in inequality. Consistent with the graphical analysis, the numbers show that composition effects fully accounted for the overall inequality change, while wage structure effects compensated each other, resulting in a combined effect of zero. For our

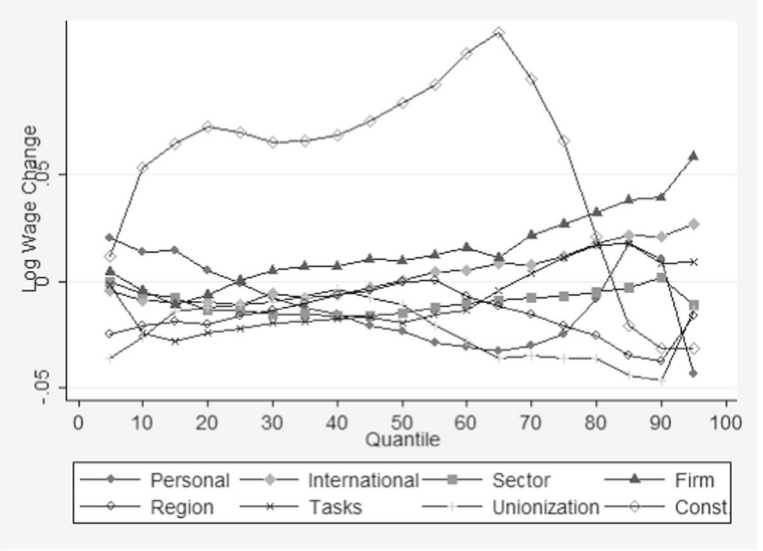

Fig. 5 Wage structure effects 1995-2010

main inequality measure, the 85-15 log wage differential, the strongest composition effects came from de-unionization (12.08 out of 19.83 points) and from personal characteristics (4.63 out of 19.83 points). Some smaller compositional effects were contributed by internationalization (1.72 out of 19.83 points) and by shifts in occupational tasks (1.18 out of 19.83 points). Turning to wage structure effects, there were inequality increasing wage structure effects coming from internationalization (3.10 points), firm differences (4.90 points) and tasks (4.56 points). However, these were fully compensated by inequality reducing wage structure effects related to union pay schemes (-2.98 points), regional convergence (-1.60 points), and the RIF constant (-8.54 points). As explained above, the latter represent general wage structure effects that cannot be attributed to any particular group of covariates. The results for the Gini coefficient and the variance of logs generally reproduce the results for the 85-15 log wage gap (columns five and six of Table 3).

Distinguishing between effects on the upper half (85-50 log wage differential) and on the lower half of the distribution (50-15 log wage differential), we find that the same groups of covariates generally turn out significant, but that the effects in the upper half of the distribution generally dominate. This is also true of the strong compositional effects of de-unionization, contrary to the results in Dustmann et al. (2009, 2014), who found that de-unionization affected mainly the bottom of the distribution. Below, we investigate differences between Dustmann et al. (2009, 2014) and our results in more detail, and provide an explanation why de-unionization affected the whole of the distribution rather than just the bottom.

The last three columns of Table 3 display the results for top 10 percent of the distribution. As shown earlier, most of the inequality increase occurred at the very top, i.e. within the top 5 percent. Compared to the rest of the distribution, we find weaker composition effects and much stronger unexplained wage structure effects. Overall, the patterns found for the top 10 percent of the distribution look more erratic and less precisely estimated. Also, specification errors are larger than in the main part of the distribution. The main conclusion is that the factors responsible for changes in the main part of the distribution do not explain changes at the top.

5.4 How do data features drive the results?

One of the contributions of this paper is to use a data set that is different from most of the data sets used in the literature on changes in the German wage distribution. As explained above, our data have a number of features that are not available in the administrative data often used for Germany. These include i) the availability of hourly wages, ii) no top censoring at the social security contributions threshold, and iii) the availability of information on union-determined pay at the individual level. The purpose of this section is to artificially impose in our data set the restrictions present in the administrative data in order to see how this influences the results. This will allow us to assess differences between our results and those reported in the literature. As most of the literature has focussed on West Germany, we also include a variation that uses West German workers only. Taken together, we consider the following variations: i) we consider daily earnings (as in the administrative data) rather than hourly wages, ii) we consider daily earnings and in addition artificially censor our wage information at the social security contributions ceiling,[10] iii) we only use the West

[10]For this variation, we proceed exactly as it is done in the literature using administrative data, i.e. we impute wages above the social security contributions ceiling based on the procedure described in Gartner (2005).

Table 3 Aggregated RIF-decompositions 1995-2010

Inequality measure	85-15	85-50	50-15	Gini	Logvar	99-90	99-95	95-90
Total change	19.21***	8.93***	10.28***	4.61***	6.21***	7.26***	6.23***	1.03**
	(0.93)	(0.73)	(0.64)	(0.20)	(0.27)	(1.00)	(0.89)	(0.45)
Total Composition	19.83***	13.68***	6.14***	6.09***	7.06***	5.50***	0.06	5.44***
	(0.67)	(0.55)	(0.48)	(0.17)	(0.21)	(0.82)	(0.68)	(0.39)
Personal	4.63***	3.32***	1.32***	1.38***	1.61***	0.70**	0.41*	0.29**
	(0.26)	(0.18)	(0.13)	(0.06)	(0.08)	(0.27)	(0.24)	(0.15)
International	1.72***	1.49***	0.24	0.47***	0.51***	−0.46	−0.94**	0.49***
	(0.38)	(0.33)	(0.26)	(0.09)	(0.11)	(0.49)	(0.44)	(0.18)
Sector	−0.13	−0.45**	0.31	0.06	0.09	1.29***	1.00***	0.29*
	(0.27)	(0.23)	(0.29)	(0.07)	(0.09)	(0.41)	(0.33)	(0.15)
Firm	−0.13	−0.02	−0.11	−0.01	−0.03	0.27	0.29	−0.02
	(0.15)	(0.09)	(0.16)	(0.03)	(0.04)	(0.24)	(0.21)	(0.07)
Region	0.48**	0.08	0.40**	0.08*	0.14**	−0.05	−0.12	0.06
	(0.22)	(0.10)	(0.17)	(0.05)	(0.07)	(0.15)	(0.12)	(0.06)
Task	1.18***	0.86***	0.31***	0.30***	0.31***	−0.03	0.03	−0.06
	(0.20)	(0.14)	(0.08)	(0.05)	(0.06)	(0.13)	(0.11)	(0.06)
Unionization	12.08***	8.41***	3.67***	3.82***	4.44***	3.77***	−0.61	4.38***
	(0.42)	(0.31)	(0.18)	(0.11)	(0.13)	(0.53)	(0.44)	(0.25)
Total Wage Structure	0.15	−3.21***	3.36***	0.04	0.55**	6.85***	5.52***	1.33**
	(0.82)	(0.67)	(0.63)	(0.18)	(0.23)	(1.52)	(1.41)	(0.59)
Personal	0.30	4.11***	−3.80***	−0.68**	−1.11***	−8.82***	−3.48	−5.34***

Table 3 (continued)

Inequality measure	85-15	85-50	50-15	Gini	Logvar	99-90	99-95	95-90
	(1.03)	(0.91)	(0.66)	(0.28)	(0.36)	(2.39)	(2.29)	(1.02)
International	3.10***	2.11***	0.99	0.65***	0.81***	0.14	−0.42	0.56
	(0.85)	(0.66)	(0.61)	(0.22)	(0.29)	(1.59)	(1.33)	(0.63)
Sector	0.41	1.17	−0.76	−0.04	−0.11	−4.04**	−2.77**	−1.28
	(0.89)	(0.82)	(0.55)	(0.25)	(0.31)	(1.64)	(1.27)	(0.86)
Firm	4.90**	2.85	2.05	1.26**	1.59**	5.72**	3.74	1.97
	(2.47)	(1.86)	(1.48)	(0.57)	(0.78)	(2.73)	(2.57)	(1.20)
Region	−1.60*	−3.41***	1.81***	0.01	0.02	4.62***	2.55**	2.07***
	(0.88)	(0.70)	(0.65)	(0.19)	(0.26)	(1.35)	(1.13)	(0.52)
Tasks	4.56***	3.74***	0.82	0.73***	0.77***	−2.83*	−2.90*	0.07
	(1.03)	(0.90)	(0.69)	(0.23)	(0.29)	(1.69)	(1.49)	(0.80)
Unionization	−2.98**	−3.34**	0.37	−0.36	−0.26	5.25***	1.99	3.27***
	(1.42)	(1.51)	(1.11)	(0.29)	(0.39)	(1.45)	(1.22)	(0.86)
Constant	−8.54**	−10.42***	1.88	−1.53*	−1.15	6.82	6.81	0.00
	(3.52)	(3.05)	(2.19)	(0.81)	(1.11)	(6.15)	(4.97)	(2.43)
Specification Error	−0.85	−0.18	−0.66*	−1.29***	−1.27***	−3.35***	1.50	−4.85***
	(0.61)	(0.50)	(0.36)	(0.12)	(0.15)	(1.02)	(1.07)	(0.55)
Reweighting Error	0.08	−1.36***	1.44***	−0.23***	−0.13	−1.73***	−0.84***	−0.89***
	(0.39)	(0.29)	(0.21)	(0.09)	(0.11)	(0.30)	(0.23)	(0.12)

Source: Structure of Earnings Surveys 1995, 2001, 2006, 2010 and own calculations

Log wage differentials × 100. Bootstrapped standard errors clustered at establishment level in parentheses (100 replications)

***/**/* statistically significant at 1%/5%/10%-level

German part of our sample, and finally, iv) we include union coverage status at the *firm* rather than at the *individual* level.

The results are shown in Table 4. A first important conclusion from this table is that the practice of the previous literature to focus on daily earnings instead of hourly wages does not change the results in any important way.[11] Similarly, introducing in addition artificial censoring at the social security contributions threshold in combination with an imputation procedure above this threshold, does not change the results in important ways, as long as one only considers the distribution up to the 85th wage percentile. However, the right hand columns of Table 4 warn that this is not true for the range above the 85th percentile or if one uses inequality measures that include the whole range of the distribution such as the Gini.[12] As a next variation, we restrict our estimates to West Germany. Considering only West Germany induces some smaller changes in the wage structure effects (esp. for personal characteristics), but does not challenge in any way the strong composition effects contributed by de-unionization and personal characteristics.

Finally, we consider the variation of using *firm level* instead of *individual level* union coverage. This produces substantial differences. In the specification with firm level union coverage, the compositional de-unionization is drastically reduced (from 12.08 to 3.37 points), and the wage structure effects for personal characteristics and union coverage are reversed. Note that it is quite plausible that reducing information on union coverage to the firm level shifts explanatory power to coefficients on personal characteristics. Switching to firm-level union status also practically *eliminates* the strong compositional effects of de-unionization found for *the upper half* of the distribution in our original specification (column three of Table 4).

How can the substantial differences between the results with individual-level and firm-level coverage status be explained? If firm-level union status is used, all individuals in the same firm are assigned an identical union effect, ignoring that not all workers in a given firm are paid according to union pay schemes. In Table 1, we showed that such workers exist and that their share increased over time. Indeed, the subgroup of workers not paid according to union pay schemes is very diverse, including both high-productivity workers for whom non-coverage is used to pay higher wages, and low-productivity workers for whom non-coverage is used to pay particularly low wages. As shown earlier, both between- and within-group wage differentials are much more pronounced in the group of uncovered than in the group of covered workers (Tables OA1 and OA2 in the online Appendix). Increasing the very heterogenous portion of workers not covered by union pay schemes will therefore mechanically increase inequality across the whole distribution, not only in the lower part.

We are now in the position to contrast our results with results reported in the literature and to explain observed differences. Using administrative data on daily earnings, Dustmann et al. (2009, 2014) also obtained the result that de-unionization was a leading factor for rising wage inequality in Germany, along with compositional changes in personal characteristics. We have shown in this paper that the use of daily earnings and censored wage information in the administrative data does not compromise the validity of their findings. Moreover, we provide a further validation of some of their conclusions by showing that the compositional effects of de-unionization and personal characteristics also hold in a multivariate setting,

[11] The only substantial difference between the analysis of hourly vs. daily wages is the RIF-regression constant. In addition, there are minor differences in wage structure effects in the lower and the upper half of the distribution (esp. for personal characteristics).

[12] Additional graphical evidence presented in the online Appendix suggests that the imputation procedure produces nonsensical patterns for distributional analysis above the 85 percentile (Tables OA5-OA8).

Table 4 Aggregated RIF-decompositions 1995-2010, alternative specifications (main specification in bold face)

Inequality measure	85-15	85-50	50-15	Gini	Logvar	99-90	99-95	95-90
Total composition	**19.83**	**13.68**	**6.14**	**6.09**	**7.06**	**5.50**	**0.06**	**5.44**
Spec. Daily earnings	18.14	12.85	5.29	5.63	6.44	4.37	−0.51	4.88
Spec. Daily earnings censored	18.29	13.00	5.29	4.71	5.50	−3.36	−2.46	−0.90
Spec. West Germany	18.75	14.33	4.42	5.89	6.40	4.76	0.22	4.54
Spec. Firm-level unionization	12.46	7.83	4.63	3.69	4.32	4.13	1.51	2.62
Composition Personal	**4.63**	**3.32**	**1.32**	**1.38**	**1.61**	**0.70**	**0.41**	**0.29**
Spec. Daily earnings	4.32	2.97	1.34	1.30	1.50	0.70	0.15	0.56
Spec. Daily earnings censored	4.38	3.03	1.34	1.38	1.58	1.16	0.40	0.76
Spec. West Germany	5.49	3.88	1.61	1.56	1.72	0.56	0.58	−0.02
Spec. Firm-level unionization	4.97	3.56	1.41	1.49	1.74	0.91	0.42	0.49
Composition International	**1.72**	**1.49**	**0.24**	**0.47**	**0.51**	**−0.46**	**−0.94**	**0.49**
Spec. Daily earnings	1.36	1.33	0.03	0.43	0.45	−0.02	−0.67	0.65
Spec. Daily earnings censored	1.37	1.34	0.03	0.39	0.41	−0.19	−0.22	0.03
Spec. West Germany	1.23	1.46	−0.23	0.37	0.38	−0.47	−0.85	0.38
Spec. Firm-level unionization	2.27	1.95	0.32	0.67	0.73	−0.23	−0.97	0.74
Composition Sector	**−0.13**	**−0.45**	**0.31**	**0.06**	**0.09**	**1.29**	**1.00**	**0.29**
Spec. Daily earnings	−0.10	−0.20	0.10	0.06	0.08	1.29	1.07	0.22
Spec. Daily earnings censored	−0.12	−0.22	0.10	0.01	0.02	0.57	0.37	0.20
Spec. West Germany	−0.31	−0.32	0.01	0.02	0.01	1.28	0.85	0.43
Spec. Firm-level unionization	0.01	−0.27	0.28	0.12	0.17	1.46	1.03	0.43
Composition Firm	**−0.13**	**−0.02**	**−0.11**	**−0.01**	**−0.03**	**0.27**	**0.29**	**−0.02**
Spec. Daily earnings	−0.13	−0.02	−0.11	−0.01	−0.02	0.31	0.27	0.04
Spec. Daily earnings censored	−0.14	−0.03	−0.11	−0.03	−0.04	0.16	0.11	0.04
Spec. West Germany	−0.17	−0.02	−0.15	−0.02	−0.04	0.41	0.42	−0.01
Spec. Firm-level unionization	0.11	0.22	−0.12	0.10	0.08	0.43	0.21	0.23
Composition Region	**0.48**	**0.08**	**0.40**	**0.08**	**0.14**	**−0.05**	**−0.12**	**0.06**
Spec. Daily earnings	0.34	0.00	0.34	0.06	0.11	−0.03	−0.04	0.01
Spec. Daily earnings censored	0.33	−0.01	0.34	0.07	0.12	0.21	0.11	0.10
Spec. West Germany	0.10	0.01	0.09	0.01	0.02	−0.05	−0.04	−0.01
Spec. Firm-level unionization	0.44	0.07	0.37	0.07	0.13	−0.12	−0.16	0.03
Composition Task	**1.18**	**0.86**	**0.31**	**0.30**	**0.31**	**−0.03**	**0.03**	**−0.06**
Spec. Daily earnings	1.10	0.77	0.33	0.29	0.30	−0.01	−0.09	0.08
Spec. Daily earnings censored	1.10	0.77	0.33	0.21	0.22	−0.81	−0.52	−0.30
Spec. West Germany	1.33	0.86	0.47	0.36	0.36	0.06	0.13	−0.06
Spec. Firm-level unionization	1.28	0.94	0.34	0.35	0.36	0.09	0.04	0.05
Composition Unionization	**12.08**	**8.41**	**3.67**	**3.82**	**4.44**	**3.77**	**−0.61**	**4.38**
Spec. Daily earnings	11.26	8.00	3.26	3.51	4.04	2.12	−1.20	3.32
Spec. Daily earnings censored	11.37	8.11	3.26	2.67	3.18	−4.45	−2.72	−1.74
Spec. West Germany	11.08	8.47	2.61	3.60	3.95	2.97	−0.87	3.84
Spec. Firm-level unionization	3.37	1.36	2.01	0.90	1.12	1.59	0.93	0.65

Table 4 (continued)

Inequality measure	85-15	85-50	50-15	Gini	Logvar	99-90	99-95	95-90
Total wage structure	**0.15**	**−3.21**	**3.36**	**0.04**	**0.55**	**6.85**	**5.52**	**1.33**
Spec. Daily earnings	0.77	−2.02	2.78	0.56	1.12	8.18	6.39	1.80
Spec. Daily earnings censored	−1.06	−3.85	2.78	1.84	2.54	14.49	9.30	5.19
Spec. West Germany	0.85	−4.46	5.31	0.15	0.80	6.76	6.27	0.49
Spec. Firm-level unionization	7.08	2.18	4.90	1.65	2.57	6.06	5.15	0.91
Wage structure Personal	**0.30**	**4.11**	**−3.80**	**−0.68**	**−1.11**	**−8.82**	**−3.48**	**−5.34**
Spec. Daily earnings	−1.53	0.71	−2.23	−0.99	−1.45	−5.81	−1.73	−4.08
Spec. Daily earnings censored	−1.67	0.56	−2.23	−1.84	−2.72	−5.62	1.02	−6.64
Spec. West Germany	2.82	4.80	−1.99	−0.26	−0.54	−9.38	−5.80	−3.58
Spec. Firm-level unionization	−3.59	0.42	−4.02	−0.57	−1.53	−3.90	−3.12	−0.78
Wage structure International	**3.10**	**2.11**	**0.99**	**0.65**	**0.81**	**0.14**	**−0.42**	**0.56**
Spec. Daily earnings	1.94	1.35	0.59	0.48	0.59	0.96	0.36	0.60
Spec. Daily earnings censored	2.12	1.53	0.59	0.25	0.34	−1.45	−1.32	−0.14
Spec. West Germany	1.67	1.26	0.41	0.37	0.46	0.23	−0.04	0.26
Spec. Firm-level unionization	4.73	3.61	1.12	1.13	1.35	−1.19	−1.61	0.43
Wage structure Sector	**0.41**	**1.17**	**−0.76**	**−0.04**	**−0.11**	**−4.04**	**−2.77**	**−1.28**
Spec. Daily earnings	−0.17	0.52	−0.70	−0.17	−0.26	−3.90	−2.46	−1.44
Spec. Daily earnings censored	−0.30	0.40	−0.70	0.16	0.07	1.02	1.09	−0.07
Spec. West Germany	1.69	1.19	0.50	0.19	0.20	−2.83	−1.26	−1.57
Spec. Firm-level unionization	−0.59	0.32	−0.91	−0.10	−0.27	−1.72	−2.05	0.34
Wage structure Firm	**4.90**	**2.85**	**2.05**	**1.26**	**1.59**	**5.72**	**3.74**	**1.97**
Spec. Daily earnings	3.01	1.48	1.53	0.94	1.15	4.01	2.23	1.78
Spec. Daily earnings censored	3.04	1.51	1.53	0.67	0.93	−4.48	−5.00	0.52
Spec. West Germany	2.00	1.29	0.71	0.78	1.06	6.94	5.30	1.65
Spec. Firm-level unionization	5.38	2.92	2.46	1.07	1.55	2.07	0.24	1.83
Wage structure Region	**−1.60**	**−3.41**	**1.81**	**0.01**	**0.02**	**4.62**	**2.55**	**2.07**
Spec. Daily earnings	−1.51	−1.06	−0.45	−0.06	−0.23	4.02	2.58	1.44
Spec. Daily earnings censored	−1.23	−0.78	−0.45	0.09	−0.10	0.68	−0.32	1.00
Spec. West Germany	−3.63	−3.80	0.17	−0.60	−0.65	3.22	2.19	1.03
Spec. Firm-level unionization	−0.46	−1.59	1.13	0.26	0.14	2.99	1.95	1.05

Table 4 (continued)

Inequality measure	85-15	85-50	50-15	Gini	Logvar	99-90	99-95	95-90
Wage structure Task	**4.56**	**3.74**	**0.82**	**0.73**	**0.77**	**−2.83**	**−2.90**	**0.07**
Spec. Daily earnings	2.54	2.82	−0.28	0.54	0.46	−2.26	−1.82	−0.44
Spec. Daily earnings censored	1.71	1.99	−0.28	0.04	−0.15	2.04	2.62	−0.58
Spec. West Germany	3.96	3.06	0.89	0.88	1.02	−2.11	−1.91	−0.21
Spec. Firm-level unionization	4.13	3.30	0.82	0.86	0.62	−1.60	−2.08	0.48
Wage structure Unionization	**−2.98**	**−3.34**	**0.37**	**−0.36**	**−0.26**	**5.25**	**1.99**	**3.27**
Spec. Daily earnings	−1.65	−1.12	−0.53	−0.17	−0.04	2.89	1.28	1.61
Spec. Daily earnings censored	−1.41	−0.87	−0.53	0.34	0.61	1.92	0.27	1.64
Spec. West Germany	−3.94	−1.97	−1.97	−0.49	−0.58	4.04	1.79	2.25
Spec. Firm-level unionization	3.99	2.42	1.57	0.51	0.91	−4.48	−2.63	−1.84

i.e. when controlling for a large set of factors at the same time (Dustmann et al. 2009, 2014, only considered one factor at a time, not controlling for other factors). Finally, we show that Dustmann et al. (2009, 2014) underestimate and partly misinterpret the effects of de-unionization by considering only firm-level unionization status which does not show the full extent of the erosion of union coverage, and which misses effects of de-unionization in the upper part of the wage distribution.

Antonczyk et al. (2010) used two waves of the same data set we use in this study and a less extensive set of explanatory factors. Employing a methodology based on sequentially introducing explanatory factors in quantile regressions, they found no leading role for effects of de-unionization. Apart from differences in methodology, we show above that their use of firm-level union information tends to underestimate the full effect of de-unionization. Moreover, they considered only the waves 2001 and 2006, while our results suggest that there were important effects in the other waves not covered by their analysis. Ohlert (2016) analyzed administrative wage data combined with rich firm survey data (the *LIAB* data). He also found no important role for de-unionization but for firm characteristics. Ohlert (2016) employed the regression-based decomposition methodology introduced by Fields (2003) which also controls for many factors at the same time, but which does not make the classical distinction between 'composition' and 'wage structure' effects. His results are therefore hard to compare to ours.

Ehrl (2017) used a very similar method but based on administrative wage data. He concludes that occupational characteristics are important for rising wage inequality, but his analysis does not include information on union coverage, neither at the firm nor at the individual level. Finally, in an analysis similar to ours but based on administrative data, Baumgarten et al. (2018) find important effects for de-unionization but also for sectoral change. The latter result is different from ours, which is probably due to the fact that we observe a narrower range of sectors in our data set than they do in theirs. Our analysis suggests that Baumgarten et al. (2018), just as all the previous literature on wage inequality in

Table 4 (continued)

Inequality measure	85-15	85-50	50-15	Gini	Logvar	99-90	99-95	95-90
Wage structure Constant	**−8.54**	**−10.42**	**1.88**	**−1.53**	**−1.15**	**6.82**	**6.81**	**0.00**
Spec. Daily earnings	−1.86	−6.72	4.86	−0.02	0.89	8.27	5.94	2.33
Spec. Daily earnings censored	−3.33	−8.19	4.86	2.13	3.55	20.39	10.94	9.45
Spec. West Germany	−3.71	−10.29	6.58	−0.73	−0.15	6.66	6.01	0.65
Spec. Firm-level unionization	−6.51	−9.22	2.71	−1.51	−0.20	13.87	14.46	−0.59
Specification Error	**−0.85**	**−0.18**	**−0.66**	**−1.29**	**−1.27**	**−3.35**	**1.50**	**−4.85**
Spec. Daily earnings	−1.40	−0.63	−0.77	−1.31	−1.28	−2.59	1.61	−4.20
Spec. Daily earnings censored	0.26	1.04	−0.77	−1.12	−1.12	0.81	1.80	−0.99
Spec. West Germany	−1.59	−0.41	−1.17	−1.29	−1.19	−1.54	1.54	−3.08
Spec. Firm-level unionization	−1.32	−0.37	−0.95	−0.71	−0.82	−0.72	0.82	−1.54
Reweighting Error	**0.08**	**−1.36**	**1.44**	**−0.23**	**−0.13**	**−1.73**	**−0.84**	**−0.89**
Spec. Daily earnings	0.18	−0.69	0.86	−0.12	−0.07	−1.50	−0.95	−0.55
Spec. Daily earnings censored	0.20	−0.67	0.86	−0.04	0.03	−0.51	−0.15	−0.36
Spec. West Germany	0.56	−1.23	1.79	−0.12	−0.00	−1.90	−0.87	−1.03
Spec. Firm-level unionization	0.99	−0.71	1.70	−0.02	0.13	−2.20	−1.25	−0.96

Source: Structure of Earnings Surveys 1995, 2001, 2006, 2010 and own calculations

Germany, grossly underestimate the leading role of de-unionization as their data does not include information on union coverage at the individual level.

5.5 What role is left for unobserved firm heterogeneity?

In light of recent contributions focussing on firm and establishment effects (Card et al. 2013; Ohlert 2016; Barth et al. 2016; Song et al. 2019), one might ask what role is left for between-firm differences that go beyond the differences in observable firm characteristics already included in our analysis. In order to address this question, we carry out the following procedure. First, we obtain cross-sectional firm effects by regressing log hourly wages on our list of observable covariates and a full set of firm dummies. Because of partitioning properties of OLS, this is equivalent to taking the residuals from wage regressions as in

Table 2 and computing average residuals at the firm level. We then consider the distribution of these firm-specific wage effects. In order to assess to what extent rising heterogeneity in firm-specific wage effects contributed to rising wage inequality, we assign to each individual in the wage distribution of a base year the corresponding firm effect in the distribution of the target year, assuming that the individual keeps working at a firm in the same percentile of the distribution of firm effects. We are aware that we are unable to capture changes in sorting of workers to firms as in Card et al. (2013) in this way.

Still, our procedure will be informative about the quantitative importance of changes in heterogeneity between firms not captured by our firm level observables (net of additional sorting effects).

Table 5 shows that assigning workers in 1995 their (more heterogenous) firm effects of 2010 increases the 85-15 wage gap by a moderate 1.72 log percentage points. This accounts for some 10 percent of the overall inequality change of 18.43 log percentage points. Overall, we conclude that rising heterogeneity between firms beyond the factors explicitly included in our analysis mattered for rising wage inequality but that its contribution was limited compared to the effects explicitly analyzed in the previous sections.

6 Summary and discussion

This paper has analyzed the quantitative importance of a large set of explanatory factors for the evolution of the German wage distribution over the period 1995 to 2010. A distinguishing feature of our analysis is that we simultaneously take into account most of the factors considered in the literature so far, and that we base our analysis on different data than used in most of the prominent studies on wage inequality in Germany. In contrast to the administrative data sets usually analyzed for Germany, our data include information on hourly wages instead of daily earnings, is not top-coded, and contain richer information at the individual level, esp. information on individual union coverage.

We explicitly analyze the differences induced by these data features. Our results suggest that analyses based on administrative data are not compromised by the fact that these data typically only report daily earnings rather than hourly wages (which are the best measure of relative prices in the labor market). Similarly, top-coding does in general not invalidate distributional results, as long as they do not include information above the 85th percentile. Using our largely uncensored wage information, we also do not find extreme movements in the upper part of the German wage distribution that is subject to top-coding in administrative

Table 5 Effect of unobserved firm heterogeneity 1995-2010

Inequality measure	85-15	85-50	50-15	Gini	Logvar
Total change	18.43	8.83	9.59	4.44	6.35
Unobserved firm heterogeneity	1.72***	0.79***	0.93***	0.47***	0.64***
	(0.17)	(0.09)	(0.10)	(0.05)	(0.07)

Source: Structure of Earnings Surveys 1995, 2001, 2006, 2010 and own calculations

Bootstrapped standard errors clustered at establishment level (100 replications)

***/**/* statistically significant at 1%/5%/10%-level

data, in contrast to what is known for other countries. This is good news for the users of administrative data which often suffer from limitations due to their administrative purpose. However, an important conclusion from our analysis is that using firm-level information on unionization may miss an important part of the erosion of union coverage if this erosion also takes place *within* firms.

In substantive terms, our study suggests that compositional effects due to de-unionization were by far the most important factor behind recent rises in wage inequality in Germany. Our analysis suggests that the inequality increasing effects of de-unionization were mainly due to the fact that de-unionization shrank the part of the economy in which wages were more compressed. We document this by showing that wages among workers covered by union agreements were much more compressed than among uncovered workers, both along observable characteristics (such as age or education), and along unobservable characteristics (within groups of workers with identical observable characteristics). It is therefore more than plausible that a shift of more than 34 percentage points from the covered to uncovered portion of the workforce led to substantially higher wage inequality. As the second most important factor for changes in the distribution, we measure compositional effects related to personal characteristics, especially workers' age and education. Such effects are consistent with the hypothesis that the increasing demand for higher skills due to SBTC were matched by rising supply for such skills in the form of educational upgrading and population aging (higher age represents higher human capital in the form of richer work experience and acquired skills). This is because in the absence of rising demand due to SBTC, rising supply of high skills would have depressed the wage premia paid for such skills, which one does not observe.[13]

Taken together, our analysis suggests that a large part of changes in the German wage distribution can be explained by compositional changes of the workforce (around 60 percent by de-unionization and around 25 percent by compositional changes in personal characteristics). We do measure some wage structure effects related to internationalization, firm heterogeneity, task changes, and regional wage convergence, but these are smaller in magnitude and tend to compensate each other.

We emphasize that our estimates are certainly not to be interpreted as causal effects. This is for several reasons, one being that the factors in our analysis might be dynamically related to each other. For example, de-unionization might have been a consequence of internationalization (e.g. Dreher and Gaston 2007). In a previous version of this paper (Biewen and Seckler 2017), we explicitly considered this possibility by placing union coverage at the end of a sequential conditioning scheme using the method of DiNardo et al. (1996), with the result that it robustly remained the most important explanatory factor. Even if a factor like de-unionization was itself a consequence of another factor, it would still be relevant to see that changes in the distribution were largely mediated by this factor. In a broader perspective and in line with Dustmann et al. (2014), de-unionization might have been a way for the German economy to arrive at a wage structure consistent with the needs of the economy. Our finding that the decline in union coverage was a major determinant of the recent rise in wage inequality is also consistent with the fact that de-unionization substantially slowed down towards the end of our observation period, and that newer data for Germany indicate no further increases in wage inequality after 2011 (Möller 2016).

[13] In the previous version of this paper, Biewen and Seckler (2017), we present some evidence for excess demand for higher skills.

Appendix

Table 6 Descriptive statistics

Variable	1995		2001		2006		2010	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Personal								
Age 20-25	0.081	0.273	0.071	0.256	0.069	0.253	0.069	0.254
Age 26-30	0.152	0.359	0.106	0.308	0.095	0.294	0.100	0.300
Age 31-35	0.176	0.381	0.169	0.375	0.122	0.327	0.108	0.311
Age 36-40	0.150	0.357	0.190	0.393	0.178	0.382	0.132	0.338
Age 41-45	0.132	0.339	0.161	0.368	0.191	0.393	0.184	0.387
Age 46-50	0.109	0.312	0.134	0.340	0.158	0.365	0.183	0.387
Age 51-55	0.121	0.326	0.106	0.308	0.121	0.326	0.141	0.348
Age 56-60	0.078	0.268	0.063	0.242	0.066	0.249	0.083	0.276
Tenure 0-5	0.403	0.491	0.406	0.491	0.360	0.480	0.349	0.477
Tenure 6-10	0.185	0.388	0.188	0.391	0.205	0.404	0.189	0.392
Tenure 11-15	0.114	0.317	0.143	0.351	0.138	0.345	0.143	0.350
Tenure 16-20	0.100	0.300	0.084	0.278	0.115	0.319	0.117	0.322
Tenure 21-25	0.085	0.279	0.076	0.265	0.071	0.257	0.086	0.280
Tenure >25	0.113	0.316	0.103	0.303	0.110	0.313	0.116	0.321
Lower/middle secondary without vocational training	0.140	0.347	0.127	0.333	0.104	0.305	0.097	0.296
Lower/middle secondary with vocational training	0.711	0.453	0.680	0.467	0.663	0.473	0.644	0.479
Upper secondary (German high school equivalent)	0.026	0.158	0.039	0.195	0.051	0.219	0.053	0.224
University of Applied Science (Fachhochschule)	0.043	0.203	0.050	0.218	0.052	0.221	0.052	0.222
University	0.032	0.177	0.045	0.207	0.051	0.220	0.055	0.227
Missing information	0.048	0.213	0.059	0.235	0.080	0.272	0.100	0.300
Non-skilled blue collar	0.218	0.413	0.236	0.424	0.221	0.415	0.236	0.424
Skilled blue collar and foremen	0.462	0.499	0.396	0.489	0.389	0.487	0.381	0.486
White collar	0.321	0.467	0.369	0.482	0.390	0.488	0.383	0.486
Internationalization								
No Exports	0.474	0.499	0.475	0.499	0.470	0.499	0.446	0.497
Export share 1-25%	0.292	0.455	0.221	0.415	0.151	0.358	0.190	0.392
Export share 26-50%	0.077	0.267	0.071	0.257	0.038	0.191	0.130	0.336
Export share 51-100%	0.157	0.363	0.233	0.423	0.341	0.474	0.234	0.423
Offshoring (0-100%)	4.020	2.311	4.177	2.380	4.405	2.771	4.062	2.841
Imports of consumption goods (0-100%)	3.267	5.138	3.274	4.764	2.993	4.816	3.220	5.116

Table 6 (continued)

Variable	1995		2001		2006		2010	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Sector								
Mining and other quarring	0.021	0.143	0.013	0.111	0.011	0.103	0.008	0.087
Food products, beverages, tobacco	0.038	0.192	0.039	0.193	0.038	0.191	0.043	0.202
Textiles	0.015	0.122	0.010	0.101	0.009	0.094	0.008	0.090
Wood	0.012	0.109	0.013	0.111	0.011	0.105	0.010	0.100
Paper	0.014	0.119	0.014	0.119	0.013	0.113	0.014	0.118
Printing	0.020	0.141	0.023	0.150	0.020	0.139	0.011	0.103
Coke and petroleum products	0.003	0.051	0.003	0.050	0.002	0.048	0.002	0.042
Chemicals	0.045	0.207	0.042	0.200	0.038	0.190	0.039	0.194
Rubber, plastic	0.034	0.180	0.036	0.187	0.036	0.186	0.037	0.190
Non-metallic products	0.028	0.164	0.026	0.158	0.021	0.144	0.021	0.144
Basic metals	0.033	0.177	0.032	0.175	0.030	0.171	0.031	0.172
Fabricated metal products	0.062	0.241	0.070	0.255	0.069	0.254	0.069	0.253
Computer, electronic, optical products	0.035	0.185	0.042	0.201	0.040	0.197	0.026	0.159
Electrical equipment	0.030	0.172	0.036	0.186	0.038	0.192	0.035	0.185
Machinery and equipment	0.119	0.323	0.108	0.310	0.125	0.331	0.106	0.307
Motor vehicles, trailers	0.055	0.229	0.068	0.252	0.089	0.285	0.070	0.255
Other transport equipment	0.024	0.154	0.016	0.126	0.017	0.128	0.013	0.113
Furniture etc	0.021	0.142	0.021	0.143	0.017	0.129	0.048	0.213
Electricity, water, recycling	0.028	0.165	0.026	0.159	0.030	0.171	0.045	0.207
Construction	0.176	0.381	0.132	0.338	0.103	0.304	0.113	0.316
Trade of vehicles	0.032	0.176	0.038	0.192	0.044	0.206	0.046	0.210
Wholesale trade	0.076	0.266	0.086	0.281	0.098	0.297	0.113	0.317
Retail trade	0.040	0.196	0.045	0.208	0.046	0.209	0.039	0.194
Finance and insurance	0.039	0.193	0.062	0.241	0.054	0.227	0.054	0.226
Firm								
Firmsize 10-19	0.074	0.261	0.079	0.269	0.071	0.257	0.073	0.260
Firmsize 20-49	0.151	0.358	0.166	0.372	0.150	0.357	0.161	0.368
Firmsize 50-99	0.134	0.341	0.125	0.331	0.130	0.336	0.125	0.330
Firmsize 100-199	0.125	0.330	0.133	0.339	0.134	0.341	0.131	0.337
Firmsize 200-499	0.170	0.375	0.159	0.366	0.161	0.367	0.159	0.365
Firmsize 500-999	0.097	0.296	0.103	0.304	0.106	0.308	0.094	0.292
Firmsize >1000	0.250	0.433	0.236	0.424	0.247	0.432	0.258	0.437
State-owned	0.046	0.210	0.023	0.150	0.020	0.141	0.037	0.188
Region								
Schleswig-Holstein	0.026	0.158	0.023	0.149	0.024	0.152	0.026	0.160
Hamburg	0.023	0.148	0.023	0.149	0.021	0.144	0.022	0.145
Lower Saxony	0.076	0.265	0.080	0.271	0.083	0.276	0.087	0.282
Bremen	0.011	0.103	0.010	0.100	0.009	0.095	0.010	0.098
North Rhine-Westphalia	0.254	0.436	0.262	0.440	0.235	0.424	0.223	0.416

Table 6 (continued)

Variable	1995		2001		2006		2010	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Hesse	0.081	0.273	0.076	0.265	0.079	0.269	0.075	0.264
Rhineland-Palatinate	0.043	0.203	0.051	0.219	0.045	0.208	0.048	0.213
Baden-Wuerttemberg	0.163	0.370	0.171	0.376	0.177	0.381	0.167	0.373
Bavaria	0.166	0.372	0.166	0.372	0.182	0.386	0.183	0.387
Saarland	0.016	0.125	0.013	0.114	0.016	0.124	0.014	0.118
Berlin	0.027	0.163	0.019	0.137	0.017	0.129	0.021	0.144
Brandenburg	0.021	0.142	0.017	0.128	0.018	0.133	0.023	0.148
Mecklenburg-West Pomerania	0.013	0.115	0.012	0.107	0.012	0.107	0.012	0.109
Saxony	0.037	0.189	0.038	0.191	0.042	0.200	0.043	0.202
Saxony-Anhalt	0.023	0.151	0.020	0.139	0.020	0.141	0.022	0.147
Thuringia	0.019	0.137	0.021	0.144	0.022	0.145	0.025	0.155
Tasks								
Share of analytical tasks	0.276	0.142	0.290	0.150	0.293	0.151	0.290	0.151
Share of interactive tasks	0.212	0.118	0.221	0.123	0.223	0.126	0.224	0.126
Share of manual tasks	0.513	0.232	0.489	0.245	0.485	0.247	0.486	0.247
Unionization								
No union coverage	0.265	0.441	0.388	0.487	0.550	0.497	0.610	0.488
Sectoral bargaining	0.697	0.460	0.569	0.495	0.401	0.500	0.357	0.479
Firm bargaining	0.038	0.191	0.043	0.203	0.041	0.198	0.033	0.178
Observations	592.198		359.495		533.497		438.352	

Source: Structure of Earnings Surveys 1995, 2001, 2006, 2010 and own calculations. Weighted data

Table 7 Mapping of activities into task indicators

Task	Activity
Analytical	Researching, evaluating, measuring
	Designing, planning, sketching
	Correcting texts or data
	Programming
	Executing laws or interpreting rules
Manual	Equipping or operating machinery
	Repairing, renovating, reconstructing
	Manufacturing, installing or constructing
	Nursing, serving, accomodating
	Transporting
Interactive	Selling, buying, advertising
	Teaching or training
	Negotiating
	Employing, managing personnel, organizing

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