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STRUCTURAL CHANGE AND WAGE INEQUALITY: EVIDENCE FROM GERMAN MICRO DATA

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Structural Change and Wage Inequality: Evidence from German Micro Data*

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Abstract

This paper measures the impact of sectoral composition, international trade and technological progress on the rising wage gap in Germany. I find a positive effect of the increasing importance of services on the rising wage gap in Germany that is comparable to the effects of international trade and technological change. To quantify the causal relationship between the structural change of the German economy and the wage premium, I use the "Establishment History Panel" (in German: Betriebs-Historik-Panel - BHP), a detailed establishment-level data set provided by the German Federal Employment Office covering the period 1975-2010. This empirical work puts the focus on an important cause of the rising wage gap that so far has been largely ignored by the literature.

Keywords: Income Inequality, Structural Change, International Trade, Technological Change

JEL codes: F16, J31, O15, O30

*The calculations for this paper are based on the "Establishment History Panel" provided by the Research Data Centre of the German Federal Employment Agency at the Institute for Employment Research. For my research, I have access to the data via on-site use at the Research Data Centre in Nürnberg as well via remote data access. I thank the members of the data centre for running my Stata do-files and checking the log-files for violation of data protection. The establishment-level data used are confidential but not exclusive; see http://fdz.iab.de/ for any details regarding the access to the data.

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1 Introduction

There is a vast literature on growing wage inequality between different skill groups. Numerous studies identify an increasing wage gap between high-skilled and low-skilled workers throughout Europe, the United States and most other OECD countries.[1] Because the wage premium has risen while the supply of skilled workers has increased at the same time, changes in labor supply cannot be an explanation for the empirical findings (Blum (2008)). The economic literature mainly states two arguments that explain the increasing demand for skilled workers: international trade and skill-biased technological change.

International trade affects the widening wage gap through two channels: First, as the Heckscher-Ohlin model predicts, the relative demand for high-skilled workers increases if the relative price for goods that use high-skilled work intensively rises. This leads to an increasing wage gap between sectors because industries that produce goods that use high-skilled labor intensively benefit from the rise in the relative prices. Second, the relative demand for high-skilled workers rises because production stages that use low-skilled labor intensively are increasingly outsourced to low-wage countries (Feenstra and Hanson (1999)). Skill-biased technological change increases the relative demand for high-skilled workers within industries. Low-skilled workers are more and more replaced by a higher degree of automatization, and the ongoing computerization increases the required qualification of the remaining employees. Therefore, the relative demand for high-skilled workers as well as the wage gap increases.

In this paper, I focus on structural change as another possible determinant for the increasing demand for high-skilled workers that is still widely unexplored in the literature. During the last decades, the wage gap increased not only in parallel to the increasing international trade and ongoing skill-biased technological change, but also while the economies of the developed countries, such as Germany, experienced a significant structural change. The sectoral reallocation has led to systematic changes in the composition of employment, i.e. a declining employment in manufacturing and a growing employment in the service sector. The closest related literature is represented by Blum (2008) who investigates the effect of structural change, international trade and technological progress on the rising wage gap in the United States. By using aggregated industry-level data, he confirms that the rise of the skill premium occurs in parallel to the change of the sectoral composition since the 1970s. In manufacturing, the employment level as well as capital accumulation have declined, whereas they

[1] See for example Blum (2008), OECD (2008) and OECD (2011).

have increased significantly in the service sector. Blum (2008) argues that capital is relatively complementary to low-skilled labor in manufacturing but in the service sector, it is complementary to high-skilled labor. Therefore, the structural shift of the U.S. economy causes a change in labor demand, which favors an increasing wage premium of high-skilled workers. Blum decomposes the wage effects of technological change, increasing international trade, changes in the sectoral composition and other factors on the U.S. wage gap. He concludes that structural change in the U.S. economy accounts for 60% of the relative increase in wages of skilled workers between 1970 and 1996.

This paper investigates the effect of changes in the sectoral composition of the German economy on the widening wage gap and puts focus on structural change as an important cause of the rising wage gap. For that purpose, I have access to a very detailed micro data set, the "Establishment History Panel". On the basis of this data set, I am able to analyze the impact of structural change on the wage gap much more precisely than other empirical studies that use aggregated industry-level data, such as Blum (2008). First, by using industry-level data, it is only possible to examine inter-sectoral changes of the employment. If there are merely information about the employment at the industry-level, the respective analysis has to assume that all employees within an industry perform tasks that belong to this sector.[2] Thus, only changes in the total employment of the respective industry can be observed. In this empirical work, I highlight that it is not sufficient to analyze structural change solely by considering an inter-sectoral reallocation of employment. The data set I use provides evidence that besides inter-sectoral changes, there is a significant process of intra-sectoral transformation, i.e. in addition to the rise of the employment in the service sector there is an increasing share of service occupations within the manufacturing sector. By investigating the employment structure within establishments, it becomes apparent that the structural reallocation is much more meaningful after accounting for intra-sectoral changes since there is an increasing number of manufacturers that produce services.[3] Hence, all empirical investigations that are based on aggregated industry-level data underestimate structural change because they ignore any intra-sectoral changes. Second, by using industry-level data, the impact of structural change on the rising wage gap is likely to be biased since it is not possible

[2]For example, it has to be assumed that all employees of the industry "Manufacture of electric motors" perform occupations to produce electric motors and therefore they can be assigned to the manufacturing sector. In this context, there are no employees within this industry that do industry-unrelated tasks, such as administration or complementary services.

[3]Following the example from before, there is an increasing share of employees in the industry "Manufacture of electric motors" that perform service tasks.

to control precisely for a wide range of effects that also have an influence on the wage structure. For example, it is not observable if some industries have experienced a market concentration, i.e. if there is a decreasing number of establishments that have become larger over the last decades. The economic literature points out that larger firms tend to pay higher wages for high-skilled workers,[4] therefore a market concentration would foster the wage gap. In addition, industry-level data do not provide any information on the establishment structure. For example, a higher share of high-skilled employees or a rising share of female employees also increases the wage gap. This implies that industry-level data may link wage effects to structural change that are in fact caused by other factors which would lead to an overestimation of the wage effects of structural change.

The main contribution of the current paper to the literature is thereby the analysis of a rather unheeded cause for the rising wage gap by estimating the effects of structural change with a very detailed and unique establishment-level data set. I have a detailed insight into the German economy and observe the structural change over the last three decades very closely. Therefore, I am able to determine inter-sectoral movements as well as intra-sectoral changes of the employment on the basis of the occupational structure within the establishments. This leads to a very precise identification of the true extend of structural change in contrast to empirical analyses using industry-level data. Furthermore, the micro data set allows me to control for a wide range of additional variables at the establishment-level that also affect the wage gap, such as the share of high-skilled employees, the share of female employees and the firm size. In addition, I am able to control for the large establishment and industry heterogeneity within Germany. Therefore, to my knowledge, this paper provides the first analysis that accounts for these additional, important information that other studies, such as Blum (2008) and OECD (2011)[5] disregard and allows for a very precise identification of another determinant for the rising wage gap in Germany.

I focus my empirical analysis on Germany by using the "Establishment History Panel" (in German: Betriebs-Historik-Panel - BHP), a detailed establishment-level data set provided by the German Federal Employment Office covering the period 1975-2010. On the basis of the BHP, I am particularly interested to analyze the transition of the

[4]See Oi and Idson (1999) for a review of the empirical literature.

[5]Blum (2008) analyzes the impact of wage inequality in the U.S. by constructing a multi-sector general equilibrium model and decomposing the effects of the structural change, international trade and technological progress on the wage premium. For the empirical analysis, Blum (2008) uses sectoral data at a 2-digit level from 1970 to 1996. In contrast to this, the OECD explains the determinants of the rise in wage inequality with international trade, technological progress and changes in labor market institutions by using a fixed-effect model with data at the macro-level for all OECD countries from the early 1980s to 2008.

German economy and the effects on wage inequality. In contrast to other studies, such as OECD (2011) that consider all kinds of income[6] to analyze the rising income inequality, this paper focuses on wages since the wage gap is the driving force behind the increasing income inequality (OECD (2011)). For that purpose, I have access to an extensive micro data set that covers 36 years and provides a detailed insight into a 50% sample of all German establishments in a given year. The BHP contains valuable information on establishment characteristics, e.g. the date of first and last appearance, the 3-digit sector classification of the respective economic activity of the establishment, and the region where the establishment is located. Furthermore, the BHP includes information about the general employment structure (e.g. number of employees), the structure of employees by educational and vocational qualifications, the structure of employees by Blossfeld occupational groups,[7] the wage structure and activities in research and development. To control for the effects of international trade, I include sectoral data on exports and imports for Germany.

The data show that the German economy changed significantly in the last three decades and thus confirm the findings of Blum (2008) for the United States. In the 1975-2010 period, the wage gap, calculated as the difference between the top and the bottom quartile of the wage distribution, increased by almost 26%. At the same time, the share of employment in the manufacturing sector decreased from 55% to 38% and increased in the service sector from 45% to 62%. Due to the information concerning the structure of employees by Blossfeld occupational groups, it is possible to distinguish between the tasks of the employees within an establishment and account for intra-industry changes. On the basis of this information, structural change is even more striking. This means that it is not sufficient to consider solely inter-sectoral movements. Starting from almost equal shares in 1975, services account for 69% of the employment in 2010. This trend is also reflected in the capital accumulation between manufacturing and services. Especially in the 1990s after German reunification, capital accumulated largely in the service sector. Moreover, the data highlight that the rise of the employment in services has not led to an equal increase of all service occupations. It can be shown that the higher the required qualification level of an occupational group is, the higher is its growth in employment. Therefore, structural change contributes to the increasing relative demand for high-skilled workers and the increasing wage gap in a similar way than skill-biased technological change.

The empirical analysis is conducted as follows. The dependent variable, wage inequality, is measured as the difference between the top and the bottom quartile of

[6]For example wages, capital income, etc.

[7]For further information, see also Appendix 1 and Blossfeld (1987).

the wage distribution in a respective establishment. To ensure meaningful wage quartiles, only establishments with at least eight employees are included in the calculation. The independent variables in which I am particularly interested are the structural composition of an establishment, international trade and technological progress. The structural composition is measured as share of employees in a given establishment with tasks in services or administration. To control for increasing trade, I use sectoral export and import data for Germany. Technological progress is measured by the number of engineers and scientists within an establishment. I estimate the impact of these variables on the German wage gap by a fixed-effects model, which includes various control variables at the establishment-level, time and industry dummies and controls for the unobserved establishment heterogeneity. To check for the robustness of my results, I run various specifications of the fixed-effects model. In addition, I also calculate my estimation by a pooled-OLS and random-effects model.

The results show that the structural composition has a significant positive effect on the wage gap. If the share of employees with occupations in services or administration rises by 10%, the wage gap increases by 4-7%. In addition, the effects of structural change on the wage gap is much larger within the manufacturing sector. If the estimated coefficients are standardized, i.e. corrected for different levels of aggregations, the effect of structural change decreases but is still positive, significant and comparable with the effects of international trade. I also estimate my regression model with more aggregated data and show that the wage effects of structural change would be biases and/or ignored if industry-level data would be used. These results support the proposition that structural change increases the relative demand for high-skilled workers and therefore fosters the wage gap.

The rest of the paper is structured as follows. In the next section, I give a brief overview about the causes of the increasing wage inequality that are mainly discussed in the literature. Furthermore, I introduce structural change as another reason for the rise of the wage gap and summarize some theoretical approaches that explain the driving forces of structural change. In section 3, I present some stylized facts about overall movements of wage inequality, employment and capital accumulation in Germany. Section 4 contains a detailed description of the data set that I use. Furthermore, I introduce the empirical model used to estimate the effects of structural change, international trade and technological progress on the wage gap in Germany and present the empirical findings and robustness checks. Section 5 summarizes and concludes. The appendix provides detailed information on the data I use and presents industry-specific regressions as well as the results of the robustness checks.

2 Theoretical Background

The theoretical literature mainly explains the rising wage inequality by the increase in international trade and the ongoing skill-biased technological change.
In general, international trade is supposed to affect the widening wage gap through two channels. First, according to the Heckscher-Ohlin model, the relative demand for high-skilled workers increases if the relative prices of tradable goods that use high-skilled labor intensively increase. The decline of relative prices for goods that use low-skilled labor intensively leads in accordance with the Stolper-Samuelson theorem to a decline in the wage for low-skilled workers, whereas the wage of the high-skilled workers increases. Empirical studies show that this mechanism holds for the 1970s in the U.S. (Leamer (2001)), but not for more recent periods. Berman et al. (1994) find no evidence for a significant causal relationship between changes in international trade and labor demand in U.S. manufacturing in the 1980s. Moreover, the Stolper-Samuelson theorem predicts a decline in the relative wages of high-skilled workers in unskilled-labor-abundant countries as a consequence of international trade. But, in the course of the increase in international trade, wage inequality rises in both developed and developing countries (Goldberg and Pavcnik (2007)). Second, the relative demand for high-skilled workers rises through outsourcing of production stages that use low-skilled labor intensively. Since the mid 1980s, multinational enterprises began to unbundle their production processes by creating global supply chains (Baldwin (2006)), because trade costs decreased substantially due to advances in transportation and communication technologies (Freund & Weinhold (2002)). Therefore, the outsourcing of production stages that use low-skilled labor intensively to countries with much lower wages became profitable for an increasing number of establishments in developed countries. Hence, the relative demand for low-skilled workers in the industrialized countries has declined. The empirical findings for the relationship between outsourcing and wages are very heterogeneous. Baumgarten, Geishecker & Görg (2010) investigate the effects of outsourcing in Germany and conclude that the effects strongly depend on the extent to which the respective task of a worker can be relocated abroad. The ease of relocating a workers' job is not necessarily correlated with its qualification level.[8] Taking cross-industry movements of workers into account, low- and medium skilled employees experience significant wage declines due to the relocation of their jobs. Again, this depends very much on

[8]For example, it is easy to relocate the high-skilled job of an IT specialist since this task does not necessarily require physical closeness. It is possible to communicate online and send labor in progress via email/firm intranet. In contrast, it is not possible to relocate the low-skilled job of a hairdresser or cabdriver because physical closeness is inevitable for this work.

the "offshorability" of the respective job. Other studies, e.g. Feenstra and Hanson (1999), estimate a significant outsourcing effect accounting for 15% to 24% of the rise in the demand for high-skilled workers in the U.S. between 1970 and 1996.

A second explanation for the rising wage gap in most industrialized countries is skill-biased technological change. The shift in the relative demand for skilled workers occurs in particular within rather than between industries in contrast to what the traditional trade theory predicts. Similar to the outsourcing effect, but in contrast to the Heckscher-Ohlin effect, skill-biased technological change increases the relative demand for high-skilled workers within industries. Labor saving technological progress replaces low-skilled labor by a higher degree of automatization, and the ongoing computerization raises the required qualification of the employees.[9] Numerous empirical studies support this effect. Berman et al. (1994) show for the U.S. that two-thirds of the employment changes of high-skilled workers and more than half of the wage changes happen within an industry. Berman et al. (1998) confirm the importance of this effect for developed countries, including Germany. Feenstra and Hanson (1999) find evidence that skill-biased technological change, in particular the increasing computerization, accounts for 8% to 36% of the wage gap within industries in the U.S. between 1979 and 1990.

This paper focuses on structural change as another possible source for the increasing wage gap that is widely unexplored in the literature by now. The theoretical literature explains structural change as a process at a disaggregated level behind a balanced growth path at the aggregate level of the economy that is in line with the Kaldor facts (Kaldor (1963)).[10] Clark (1940) and Kuznets (1966) describe structural change by looking at the continuous decline of agriculture in terms of output and employment that comes along with long-run increases in income per capita. Nowadays, the focus is on the increasing importance of the service sector. The systematic changes in the composition of the economy take place at a more disaggregated level (at the sector-level or industry-level) and are commonly defined as Kuznets facts (Kongsamut et al. (2001) & Alvarez-Cuadrado and Long (2011)).

Recently, the literature developed several multi-sector growth models that allow for the process of structural change and still guarantee a balanced growth path, i.e. combine the Kaldor facts with the Kuznets facts. These models can be classified into

[9] For a review, see for example Berman et al. (1994), Berman et al. (1998), Blum (2008).

[10] The literature on economic growth traditionally features in models that assume a trajectory where the growth of output, the capital-labor ratio, the return to capital and the factor income shares are (roughly) constant over all sectors. In the last decades, these Kaldor facts (Kaldor (1963)) determine the literature and, therefore, models on economic growth assume restrictions on preferences and technology to be in line with these Kaldor facts (Alvarez-Cuadrado and Long (2011)).

two groups concerning the assumption on the driving force behind structural change: preference-driven and technology-driven structural change (Alvarez-Cuadrado and Long (2011)).

In the first category, structural change is the result of different income elasticities of demand across goods (Kongsamut et al. (2001)).[11] As the economy grows and income rises, the demand of consumers changes. If e.g. capital accumulates and income per capita rises, demand (and therefore resources and production) is shifted from products with low demand elasticity, such as food, to products with high demand elasticity, such as services or luxury goods (Kongsamut et al. (2001) & Foellmi and Zweimüller (2008)). This leads to a decline of agriculture and manufacturing and an expansion of the service sector as it can be seen in the data (see Section 3).

The second category of models argue that technological differences across sectors are the driving force behind structural change. They can be classified into two different mechanisms: First, Ngai and Pissarides (2007) assume that structural change is the result of different TFP growth rates across sectors. Second, Acemoglu and Guerrieri (2008) suppose that differences in the elasticity of output to capital and therefore different factor proportions across sectors cause structural change. If sectoral TFP levels diverge or capital accumulates, these differences lead to changes in the sectoral composition and to an unbalanced growth at a disaggregated level that is in line with the Kaldor facts.

Recently, Alvarez-Cuadrado and Long (2011) developed an additional model of structural change that is consistent with balanced growth at the macro-level. By assuming sectoral differences in the elasticity of substitution between capital and labor, the authors examine another source for technology-driven structural change. Due to different degrees of "flexibility", i.e. different elasticities of substitution between capital and labor across sectors, the sectoral composition of output changes systematically if relative prices of factors of production change.[12]

In summary, there is a large body of literature that explains possible causes for structural change and the transmission channels through which the mechanisms work. All models emphasize the assumptions of the traditional literature on economic

[11] There is a vast literature about the assumption of non-homotheticity as a driving force for structural change. See for example Echeverria (1997) & Gollin, Parente and Rogerson (2007).

[12] If the aggregate capital-labor ratio increases, the more flexible sector can substitute the relatively more expensive input (labor) into the relatively cheaper input (capital) more easily. Hence, it is able to reduce the average costs of its inputs to a higher degree and will grow relatively to less flexible sectors. Therefore, differences in the sectoral elasticity of substitution between capital and labor cause a change in the sectoral composition of output since the aggregate capital stock increases.

growth by keeping the Kaldor facts but augmenting them with the Kuznets facts, i.e. developing models that ensure a balanced growth path at the aggregate level of the economy but allow for structural changes in employment and the composition of output at a more disaggregated level. In the following, I will not refer to a particular model that analyzes the causes of structural change but take the structural change as an independent process beside technological progress and international trade that affects the income distribution.

The sectoral reallocation that has taken place in Germany since 1975 has led to an expansion of the employment in the service sector and a decline of the employment in the manufacturing sector (see Section 2). Moreover, the data show that the increasing service employment has not led to an uniform rise of all service occupations. The rise of the service employment has especially strengthened the increasing demand for high-skilled workers. These findings are in line with Blum (2008). He argues that structural change leads to a change in labor demand since capital is relatively complementary to low-skilled labor in manufacturing but relatively complementary to high-skilled labor in the service sector. Therefore, there is an additional skill-bias of structural change that is similar to the effect of technological progress. Structural change leads to an increasing demand for high-skilled workers and is therefore an additional reason for the increasing wage gap.

Table 1: Growth of occupational groups
(according to the Blossfeld classification of occupations, 1975-2010)

Services	**Growth**	**Administration**	**Growth**
Unskilled services	70.78%	Unskilled commercial and administrational occupations	34.02%
Skilled Services	145.99%	Skilled commercial and administrational occupations	84.55%
Semiprofessions	343.22%	Managers	101,01%
Professions	388.20%		

Source: "Establishment History Panel", authors' computation.

Table 1 confirms the change in labor demand by comparing the growth of occupational groups related to service tasks between 1975 and 2010.[13] The different occupational

[13]The growth of an occupational group is calculated as the percentage change of the total number of full-time employees classified within this group.

groups are classified according to the Blossfeld classification of occupations[14] and describe the tasks done by the employees. Table 1 shows that occupational groups which require the highest qualification levels are characterized by the highest growth rates. While unskilled services grew only by 71%, skilled services grew more than twice as much and semiprofessions and professions even by 343%, or 388% respectively. The same holds for administrative services. Unskilled administrational occupations increased by 34% but managers by more than 100%. In summary, the findings show that the higher the required qualification level of an occupational group is, the higher is its growth. This confirms that structural change contributes to the increasing relative demand for high-skilled workers and thus to the increasing wage gap.

3 Stylized Facts

According to the OECD report "Divided We Stand: Why Inequality Keeps Rising" (OECD (2011)), income inequality in Germany rose significantly in the last decades. Here, income inequality covers all kinds of earnings, e.g. wages and capital income.

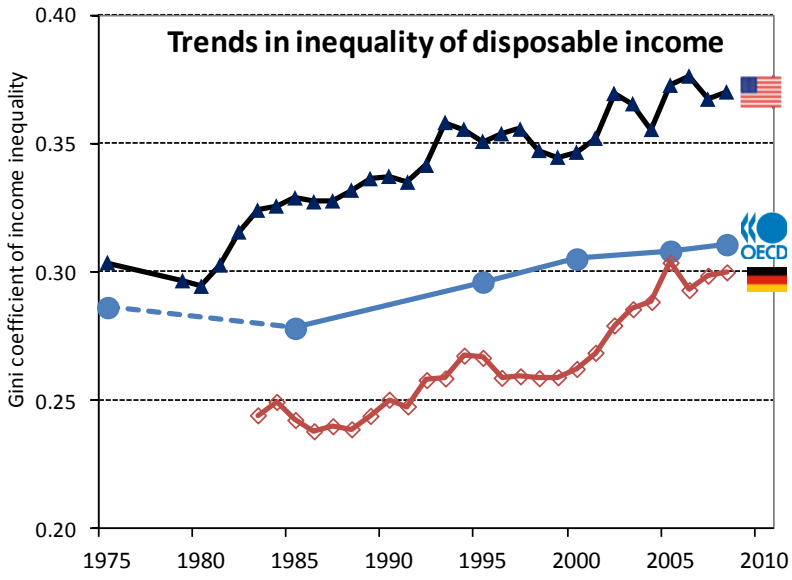

Figure 1:
Inequality in Germany measured by the Gini coefficient
(**Source:** OECD (2011a))

Figure 1 shows that German inequality increased continuously and faster than the OECD average since the end of the 1980s until today. While German inequality was

[14]For further information, see Appendix 1 and Blossfeld (1987).

close to the levels in the Scandinavian countries and substantially below the OECD average in the mid-1980s, it was almost equal to the OECD average in 2010.[15] In addition, the wage gap, measured as the wage ratio of the top 10% of the working population over the bottom 10%, rose from 6 to 1 in the 1990s to 8 to 1 today (OECD (2011)).[16] Like in the United States (Blum (2008)), the rise in income inequality occurred at the same time as the sectoral composition of the German economy changed from manufacturing to services. By using the "Establishment History Panel", an establishment-level data set provided by the German Federal Employment Office, it is possible to examine the wages and the structure of the German economy between 1975 and 2010 in detail.

Figure 2:
Wage gap in Germany
Source: "Establishment History Panel", authors' computation.

Figure 2 confirms the findings of the OECD report concerning the wage gap in Germany. The wage gap, calculated as the difference between the upper and the lower quartile of real wages, increased continuously.[17] The upper graph of Figure 2 shows

[15]OECD (2011a): In this case, inequality is calculated by the Gini coefficient.

[16]The authors calculate that the rise in income inequality in Germany is mainly driven by the increasing wage gap.

[17]The wage gap is calculated as the difference between the upper and the lower quartile of real gross daily wages of an establishment's full-time employee. For that purpose, I calculate the wage gap as the average difference over all establishments in a given year. To ensure sufficient observations for the calculation of differences in wage quartiles within an establishment, I only include establishments with at least eight employees.

the wage gap in Germany over all establishments and industries. In 1975, the average wage of employees in the upper quartile was Euro 9.65 larger than the average wage of employees in the lower quartile. Until 2010, the wage gap has increased by 26% to Euro 12.14. The lower graph illustrates the increasing wage inequality by separating the manufacturing from the service sector. It shows that the wage gap has increased in parallel in both sectors but the difference between the wage inequality within the manufacturing and within the service sector did not rise. However, the wage gap between the sectors is very different. On average, the wage gap within the service sector is 21% larger than within manufacturing. Hence, an increase in the importance in terms of employment of the service sector leads immediately to a larger overall wage gap.

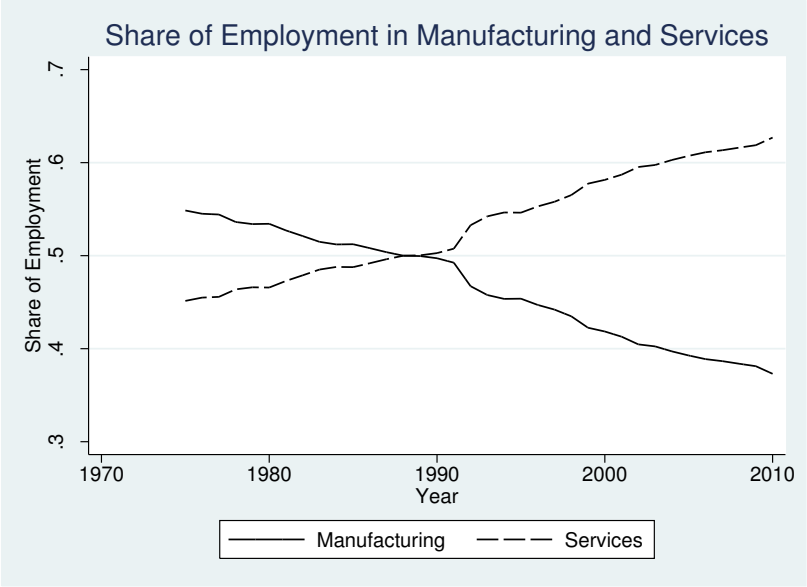

Figure 3:
Share of Employment in Manufacturing and Services
Source: "Establishment History Panel", authors' computation.

Figure 3 shows the development of employees working in the manufacturing and service sector in Germany between 1975 and 2010. It supports the point made by Blum (2008) that the wage gap has grown with changes in the sectoral composition. To calculate the share of employment, all establishments are classified into manufacturing or services on the basis of the 3-digit classification of economic activities that is

included in the BHP.[18] The data show that the share of employment in manufacturing has declined steadily whereas the share of employment in services has risen. In 1975, 55% of all workers were employed in manufacturing and 45% worked in services. Since 1975, the sectoral employment pattern has reversed. In 2010, 63% of all employees worked in the service sector and 37% were employed in the manufacturing sector.[19] Figure 3 reflects the inter-sectoral reallocation of employment that is defined as structural change according to empirical analyses on the basis of industry-level data such as Blum (2008).

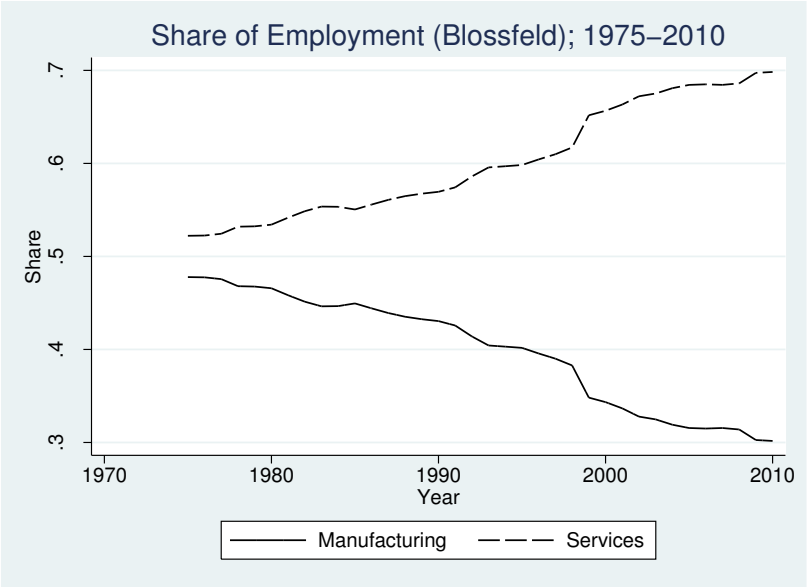

Figure 4:
Share of Employment in Manufacturing and Services
Source: "Establishment History Panel", authors' computation.

Figure 4 also illustrates the share of employment in the two sectors. Here, the variable defines the employees according to the Blossfeld classification of occupations. While the previous measurement assigns all employees of a respective establishment to the sector in which the establishment is classified,[20] this classification provides in-

[18] According to the classification of economic activities 93, every establishment is classified either into the manufacturing or in the service sector. Here, all employees of the respective establishment are assigned to the same sector as the establishment.
All establishments in the classification range 11-454 are assigned to the manufacturing sector, all establishments with the classifications 455-990 are ranged to the service sector.

For further information on the classification of industries see Appendix 3.

[19] The employment share is calculated across all qualification levels.

[20] For example, if an establishment is classified as "Manufacturer of electric motors", i.e. it is assigned to an industry in the manufacturing sector, all employees of this establishment are classified as employees in the manufacturing sector.

formation about the structure of employment within an establishment and therefore accounts for the intra-sectoral reallocation of employees. Together with the employment notification, the employer reports the task done by an employee at a 3-digit level from the classification of occupations (Hethey-Maier & Seth (2010)).[21] These data are used to recode the information according to the Blossfeld classification of occupations (Blossfeld (1987)). The Blossfeld classification arranges the tasks into 12 groups on the basis to which economic sector the respective occupation is related. In addition, the classification also distinguishes between the respective qualification level.[22] With this classification included in the BHP, it is possible to determine the structural composition of the economy more precisely since there is an increasing number of establishments in the manufacturing sector that are engaged in services (see for example Kelle (2012)).[23] The data reflect this shift. With the information about the employment structure within an establishment, the employment in services, i.e. service occupations, is much larger for the whole period. In 1975, the employment in manufacturing accounted for 48% and services for 52% of the total employment. As before, the share of employment in services increased continuously and the share of the employment in manufacturing decreased. In 2010, services accounted for 70% of the employment share. Figure 4 provides clear evidence that structural change is even more significant if intra-sectoral changes are included. It shows that there is an increasing number of manufacturers who produce services and therefore hire a growing share of employees that perform service tasks. Since most of the growing occupation in services refers to high-skilled labor[24], this leads to an increasing wage gap.

Figure 5 shows the employment levels in Germany for high-skilled and low-skilled workers.[25] The rise in employment of high-skilled employees and the steep decline in the employment of low-skilled workers confirms the ongoing change in the employment structure. In 1975, an establishment employed on average 0.5 high-skilled workers and 4 low-skilled workers. In the last decades, this changed fundamentally. In 2010, an establishment employed on average 1.3 high-skilled and 0.9 low-skilled workers. The persistent change in the employment reflects the transition of the German economy, both in terms of the structural change and skill-biased technological change.

[21] See also "Klassifikation der Berufe - KldB75".

[22] For further information, see also Appendix 1 and Blossfeld (1987).

[23] E.g. advertising, data processing, assembly and maintenance services.

[24] See Table 1, Section 2.

[25] The employment is calculated as average employees per establishment in a given year.

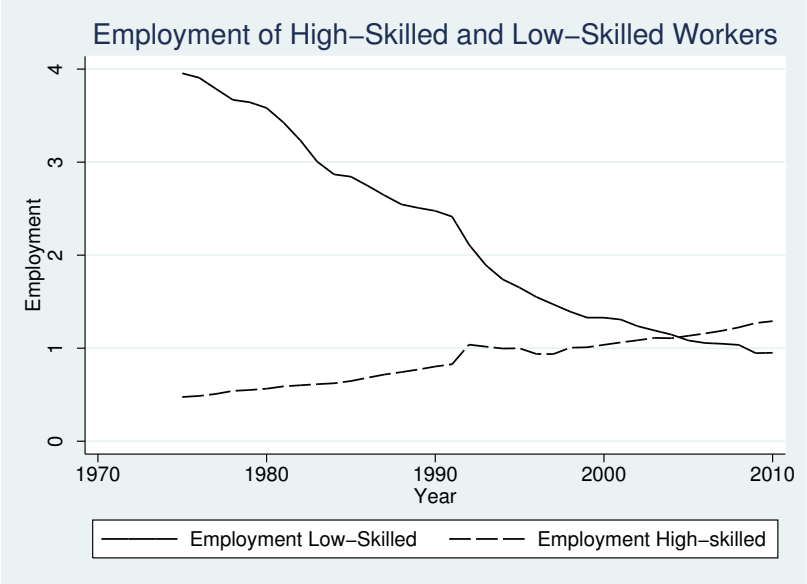

Figure 5:
Average Employment in Manufacturing and Service per establishment
Source: "Establishment History Panel", authors' computation.

Figure 6 illustrates the capital accumulation in Germany in manufacturing and services. Until 1990, capital has accumulated equally in the manufacturing and service sector, but in the 1990s, the investments in the service sector have grown more rapidly. Between 1993 and 2001, capital accumulated by almost 25% in the service sector and declined by 16% in manufacturing. These findings describe the structural change in the German economy, which are very similar to the movements Blum (2008) finds for the United States. Blum argues that capital is relatively complementary to high-skilled labor in the service sector and to low-skilled labor in the manufacturing sector. Hence, a structural change in capital accumulation causes an increase in the demand for high-skilled employees and thus an increase in the wage premium.

In summary, the sectoral composition of the German economy changed considerably. The manufacturing sector declined significantly, whereas the service sector grew. This is supported by the data in terms of the sectoral employment, the demand for high-skilled and low-skilled employees and the capital accumulation in the two sectors. Furthermore, the BHP supports the findings of the OECD (2011) and many other studies concerning the increasing wage inequality in Germany. In the period 1975-2010, the wage gap between the upper quartile and the lower quartile has increased by 26%. Moreover, the wage gap within the service sector is much larger than within the manufacturing sector. Therefore, the rise of the service sector increases the overall wage gap directly. In addition, structural change increases the relative demand for high-skilled workers which also leads to an increasing wage gap. In the following, I

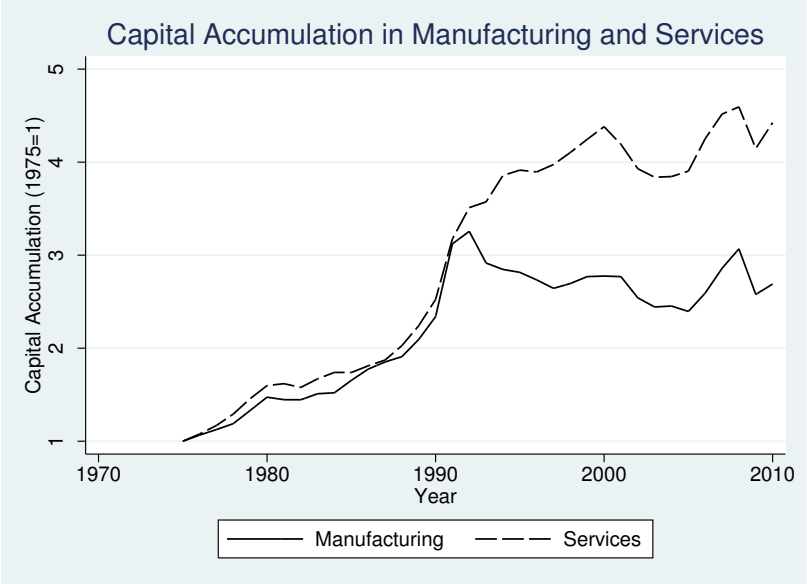

Figure 6:
Capital Accumulation in Manufacturing and Services; 1975-2010
Source: "German Federal Statistical Office", authors' computation.

will describe the data set in detail and introduce the empirical model used to calculate the effects of structural change, international trade and technological progress on the wage gap in Germany.

4 Empirical Evidence

4.1 Data

The empirical analysis is based on the "Establishment History Panel" (in German: Betriebs-Historik Panel (BHP)) provided by the Research Data Centre of the German Federal Employment Office.[26] The BHP is a unique data set covering the period 1975-2010 for establishments in Western Germany and 1991-2010 for Eastern Germany. It includes a 50% sample of all establishments in Germany with at least one employee subject to social insurance contributions before June 30th of the respective year.[27] The data base for the BHP is the Employee-History (in German: Beschäftigten-Historik (BeH)) of the IAB. By aggregating the individual data of the BeH to the establishment level and assigning establishment numbers ("artificial establishment number"), it is possible to create a panel data set for the full time period. Based on

[26]The data has been made available in autumn 2011. For my research, I have access to the data via on-site use at the Research Data Centre of the German Federal Employment Agency at the Institute for Employment Research (in German: Institut für Arbeitsmarkt- und Berufsforschung (IAB)) and via remote data access.

[27]Since 1999, establishments with at least one part-time employee are also included in the panel.

the information of the Employee-History, the BHP provides detailed information on the general employment structure, e.g. the total number of full-time and part-time employees and share of female employees, the composition of employment regarding employees' educational and vocational qualifications, the occupational status and age structure, the wage structure of full-time employees,[28] and R&D activities. In addition to these variables, the data set contains information about the establishment characteristics, e.g. the artificial establishment number, the date of first and last appearance, the district code and the 3-digit classification of economic activities.[29]
To account for the increase in international trade, I include sectoral export and import data for Germany in the data set. I use data obtained from the United Nations Commodity Trade Statistics Data Base (UN comtrade data base) at a 2-digit level for German manufacturing trade from 1978 to 2010[30] and total trade in services from the data base of the United Nations Conference on Trade and Development Data Base (UNCTAD) for the 1980-2010 period. To control for further effects on the wage gap,[31] I use data at the macro-level provided by the German Federal Statistical Office concerning German GDP and information on the level of education.[32]

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[28]The wages reported in the BHP are based on the regulations for the German social security notifications. Employers have to report the employees' gross wage subject to social security contributions for a given year. Hence, the wages are only reported up to the upper earnings limit for social security contributions in the respective year. This can lead to an underestimation of the wage gap since the upper quartile of the reported wages is cut off at this threshold, i.e. all employees that earn more than the upper earnings limit for social security contribution are included with an wage equal to the upper earnings limit.
This censoring problem of the BHP cannot be solved by the imputation of wages above the contribution limit of the social security (Gartner (2005)). The data set does not contain information about individual wages that are necessary for the imputation but only information about average wages paid in the wage quartiles of a respective establishment.

[29]For further information concerning the BHP see also Eberle (2011) and Gruhl et al. (2012).

[30]The 3-digit classification of economic activities 93 that is included in the BHP stands for "Industrial Classification of Economic Activities for the Statistical Office of the Federal Employment Agency, 1993 Edition". The first two digits are based on the ISIC, Rev.3 classification ("International Standard Industrial Classification of All Economic Activities") and contain 60 divisions. In contrast, the data on manufacturing trade from the UN comtrade data base are classified according to the "Standard International Trade Classification, Revision 2" (SITC, Rev.2) and contain articles in 63 divisions. To match the trade data with the BHP, I generate a correspondence table on the basis of Affendy et al. (2010) at a 2-digit level. Because the trade data are not available at a more disaggregated for the full time period, I have no information to distinguish between units within a 2-digit category. Therefore, individual subcategories at a 5-digit level that are constructed by Affendy et al. (2010) may be transformed incorrectly. To my knowledge, there is no methodology of correspondence between the two classifications that is more appropriate.

[31]To measure the effect of international trade and other control variables, I follow OECD (2011).

[32]Both control variables at the macro-level are only included in estimations without year fixed-effects since they would be omitted because of collinearity otherwise.
For a more detailed overview of the variables see Appendix 2.

4.2 Empirical Strategy

To explain the effects of structural change, international trade and technological progress, I follow the empirical model of the OECD (2011) study. That study uses a macro data set for all OECD countries (OECD (2011), Chapter 2) from the early 1980s to 2008 to estimate the effects of international trade, technological progress and changes in labor market institutions and policies by a fixed-effects regression analysis. In the current paper, I use a similar empirical model, but I focus on Germany in the period 1980-2010 by using a very detailed establishment-level data set. In addition, I especially evaluate the effects of the structural change in Germany by implementing an appropriate proxy, the share of employees with tasks in services or administration (see Equation (3)).

In order to calculate the effects of changes in the sectoral composition in Germany, I use the "Establishment History Panel" together with the additional data sets mentioned above. Altogether, it is a detailed panel data set covering the years 1980-2010[33] in Germany. To account for establishment heterogeneity I use the respective establishment as the panel variable and thus I am able to control for all establishment-specific effects.[34] The estimated fixed effects equation looks as follows:

$$\Delta w_{jit} = \alpha + \beta_1 Struc_{jit} + \beta_2 Trade_{it} + \beta_3 Tech_{jit} + \gamma' X_{jit} + \delta' V_t + \lambda_i + \eta_t + \epsilon_{jit}. \quad (1)$$

The dependent variable, Δw_{jit}, is the wage gap of establishment j in industry i at time t. It is calculated as the difference between the top and the bottom quartile of the wage distribution among full-time employees in an establishment:[35]

$$\Delta w_{jit} = w_{jit}^{Q.75} - w_{jit}^{Q.25} \quad (2)$$

[33] Because the data for trade in services are only available from 1980 to 2010, I have to skip the 1975-1979 period of the BHP.

[34] Each establishment is represented by its respective artificial establishment number. This number is randomly generated to make the data anonymous but it allows the identification of the same establishment in different years. Therefore, it is possible to merge the yearly data of the core data set to create a panel data set. Afterwards, I am able to control for all establishment-specific effects using the "areg" command in Stata. This is equivalent with creating dummy variables for each establishment and adding them to the regression.

[35] The BHP only provides information on the average wage of the employees in the respective wage quartile. Therefore, precisely, the wage gap is calculated as the difference between the average wage of an employee in the top quartile and the average wage of an employee in the bottom quartile.
Moreover, all estimations include establishments with at least eight employees to ensure sufficient observations within an establishment to calculate differences in wage quartiles, employment shares, etc.

The first explanatory variable, $Struc_{jit}$, measures the structural composition within an establishment. It is constructed as the share of employees in a respective establishment with an occupational status "services" (E_{jit}^{serv}) or "administration" (E_{jit}^{admin}) according to the Blossfeld classification over the total employment of the establishment, E_{jit}:[36]

$$Struc_{jit} = \frac{E_{jit}^{serv} + E_{jit}^{admin}}{E_{jit}} \tag{3}$$

$Trade_{it}$ are exports from Germany. It is an indicator that controls for the integration of the German economy in international trade. $Tech_{jit}$ is a proxy for technological progress and is measured by the number of engineers and scientists in an establishment. That information is included in the BHP to account for research and development activities. X_{jit} is a vector of control variables accounting for further influences at the establishment-level that may also have an effect on the wage gap, e.g. the size of the establishment,[37] the share of female employees and the share of high-skilled employees. V_t is a second vector of control variables that accounts for effects at the macro-level, e.g. German GDP, a dummy variable controlling for German reunification in 1991 and the education level of the German population.[38]
Equation (1) is estimated by a fixed-effects model with both industry-specific effects, λ_i, to capture sector-specific variation and year-specific effects, η_t, to control for common global shocks and business cycle effects. ϵ_{jit} is the error term. All variables are transformed into logarithms, such that the estimated coefficients can be interpreted as elasticities.[39]
To check for the robustness of the proxies for international trade, all regressions are estimated with both German export and import data. In addition, equation (1) is estimated by pooled-OLS, fixed-effects and random-effects as well on the basis of various different specifications[40].

[36] Blossfeld (1987) distinguishes between production (agricultural occupations, unskilled manual occupations, skilled manual occupations, technicians or engineers), services (unskilled services, skilled services, semiprofessions and professions) and administration (unskilled commercial and administrational occupations, skilled commercial and administrational occupations and managers. For further information see Appendix 1.

[37] The size of an establishment is measured by the number of full-time employees.

[38] The overall education level is measured as the percentage share of German citizens with post-secondary education.

[39] See also Appendix 2: Data sources and variables.

[40] See Section 4.3.2.

4.3 Empirical Findings

4.3.1 Results from the Baseline Model

Table 2: The impact of structural change, international trade and technological progress on the wage gap in Germany, 1980-2010

Variables	Fixed-Effects Regression				
	(1)	(2)	(3)	(4)	(5)
Structural Change					
Struc	0.4839***	0.4849***	0.4778***	0.4851***	0.4781***
	(0.0096)	(0.0093)	(0.0093)	(0.0097)	(0.0094)
International trade					
Exports		0.0177***	0.0174***		
		(0.0034)	(0.0034)		
Imports				0.0339***	0.0332***
				(0.0027)	(0.0029)
Technological Progress					
R&D			0.0153***		0.0151***
			(0.0014)		(0.0014)
Other Controls	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.7244	0.7243	0.7257	0.7243	0.7257
Root MSE	0.3496	0.3497	0.3497	0.3497	0.3497
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000
No. of Obs.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

Table 2 shows the estimations from the baseline regression model of equation (1). Here, the estimation includes all control variables as well as industry and year fixed-effects. First, without controlling for international trade and technological progress, column 1 in Table 2 shows that the structural composition has a positive and significant effect on the wage gap in Germany. The coefficient on structural change, β_1, suggests that a 10% increase in the share of employees with occupations in services or administration leads to a 4.8% increase of the difference between the top and the bottom wage quartile. This supports the argument that structural change leads to an increase in the relative demand for high-skilled workers and therefore to a rise of the wage gap.

Taking international trade into account, column 2 shows that the coefficient on the structural composition remains almost constant. The coefficient on international

trade, β_2, is also positive and significant but much smaller than β_1. A 10% increase in exports leads to a 0.2% increase in the wage gap, but if the share of employees with tasks in services or administration increases by 10%, the wage gap increases again by 4.8%.

Column 3 includes the effect of technological progress. The estimation shows that the impact of technological advances on the wage gap is positive and significant, too. If the the number of engineers and scientists within an establishment increases by 10%, wage inequality increases by 0.2%. Again, this effect is much smaller than the impact of the structural composition and is comparable to the effect of international trade. By including the effect of technological change, the coefficients β_1 and β_2 remain almost constant.

Columns 4 and 5 serve as robustness checks by estimating the specifications of column 2 and 3 with German import data. As the coefficients show, the effect of German imports on the wage gap is higher than the effect of German exports but it is still much smaller than the impact of structural chance. All other coefficients remain roughly constant, i.e. the results are not sensitive to changes of the measurement of international trade.

To summarize, the results show that the structural composition, international trade and technological progress have a positive and significant effect on the increasing wage gap in Germany. Moreover, the effects of changes in the structural composition of the employees are considerably larger than the effects of international trade and technological progress. These findings hold for various specifications of the estimated equation (1).

After having identified the substantial effect of structural change on the wage gap in Germany in the 1980-2010 period, I split the data set into sub periods and sectors to investigate the driving forces behind the overall effect more closely. To check whether the effect of structural change on the rising wage inequality varies in the course of time, I subdivide the data set into three periods and estimate them separately. In addition, I estimate equation (1) only with establishments in manufacturing or services[41] respectively. The results are reported in Table 3.

Column 1 of Table 3 repeats the result of Table 2, column 3. In this specification, equation (1) is estimated with all control variables, with coefficients for international trade and technological progress as well as industry and year fixed-effects for all establishments and years. Here, only the coefficient on the structural composition is reported. Again, the results show that the coefficient is positive and significant. A 10% increase in the share of employees with tasks in services or administration causes

[41] According to the classification of economic activities 93.

Table 3: Fixed-Effects estimation within sub periods and sectors

	Overall Effect	Effects in Sub Periods			Effects Within Sectors	
		1980-1990	1990-2000	2000-2010	Manufacturing	Services
	(1)	(2)	(3)	(4)	(5)	(6)
Structural Change						
Struc	0.4778***	0.3916***	0.4760***	0.4439***	0.7846***	0.1731***
	(0.0093)	(0.0238)	(0.0173)	(0.0183)	(0.0131)	(0.0133)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.7257	0.7502	0.7771	0.7864	0.7702	0.6924
Root MSE	0.3497	0.2765	0.3160	0.3311	0.3126	0.3691
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of Obs.	1.87 Mill.	419.335	733.532	731.762	690.722	1.18 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses,
*** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

a 4.8% increase in the wage gap.

To check whether this effect varies over time, I subdivide the data set into three periods: 1980-1990, 1990-2000 and 2000-2010. The results are reported in columns 2 to 4. The estimated coefficients show that the effect of structural change on the wage gap differs in the course of time. Between 1990 and 2000, a 10% increase in the share of employees with occupations in services or administration leads to a 4.8% increase in the wage gap. This effect is 22% larger than in the first sub period. Between the second and the third sub period, the coeffiecient decreases somewhat but remains almost constant. This suggest that most of the wage effects of structural change occured after 1990.[42]

Moreover, to check if the effect arises mainly in the manufacturing or in the service sector, I separately estimate equation (1) only with establishments that are classified either in the manufacturing or in the service sector. Columns 5 and 6 report the results. The outcome shows that the wage effects are mainly driven by changes in the composition of employees in the manufacturing sector. The estimated coefficient

[42] In order to check if it is sufficient to use a dummy variable to control for the effects of the German reunification in 1991, I additionally estimate equation (1) for Western Germany separately. Thus, I am able to test if the effects estimated so far might be driven by the integration of the Eastern German economy despite using the reunification dummy. The results are reported in Table 10, Appendix 7. The estimated coefficients are slightly smaller than in Table 3 but they confirm the findings above and provide evidence that the effects of structural change on the rising wage gap are not mainly driven by the transformation of the Eastern German economy after 1991. Furthermore, the results show that it is sufficient to use a dummy variable to control for the German reunification as before.

for establishments within the manufacturing sector is more than four times larger than the coefficient for service establishments only. Furthermore, I estimate equation (1) for each industry separately. The results are reported in Appendix 3 and confirm the findings above. The industry-specific regressions clearly show that the effect of structural change on the wage gap is much higher within manufacturing industries than within service industries. In services, the estimated coefficient is smaller and often, it is not significant. This result provides further evidence that an important part of structural change occurs in the manufacturing sector. There are an increasing number of manufacturers that also produce services that use high-skilled labor intensively which leads to an increasing wage gap.

Next, I estimate equation (1) with standardized coefficients. This is due to the fact that the variables that are included in the regression analysis are measured at different levels. For instance, the variable concerning the share of employees with tasks in services is measured at the establishment-level but trade data are merely available at the industry-level. Therefore, the means and variances of the independent variables differ considerably and thus, the size of the unstandardized coefficients are not directly comparable. The estimated coefficients above show that the effects of structural change, international trade and technological progress contribute to the increasing wage gap in Germany. But it is not possible to conclude from the unstandardized coefficients that the effect of structural change is many times higher compared to the effects of international trade and technological progress. To check which of the independent variables have a greater effect on the dependent variable, I re-estimate equation (1) with beta coefficients, that account for differences in the variances of the independent variables.[43] The beta coefficients can be interpreted as a change in the standard deviation of the dependent variable due to a one standard deviation change in the respective independent variable.

The results are reported in Table 4. The estimated beta coefficients show that the effect of international trade on the wage gap is much more important than the unstandardized coefficient would suggest. In addition, the the effect of structural composition is still important but much smaller than the unstandardized coefficients would assume.

First, equation (1) is estimated by a pooled-OLS model. The results show that a one standard deviation increase in the share of employees performing service tasks results in a 0.23 standard deviation increase in the wage gap. Concerning the effect

[43] Standardized (beta) coefficients are derived by multiplying the primary, unstandardized, coefficient by the ratio of the standard deviations of the respective independent variable and the dependent variable: $\beta_i^* = \beta_i \frac{S_{x_i}}{S_y}$.

Table 4: Estimation with standardized coefficients

Variables	Pooled-OLS		Fixed-Effects	
	β_i	Standardized	β_i	Standardized
Structural Change				
Struc	0.7126***	0.2341	0.4779***	0.1723
	(0.0044)		(0.0094)	
International trade				
Exports	0.0302***	0.2494	0.0175***	0.4006
	(0.0046)		(0.0034)	
Technological Progress				
R&D	0.0488***	0.0658	0.0153***	0.0145
	(0.0008)		(0.0014)	
Other Controls	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
No. of Obs.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

of international trade, the estimation suggest that a one standard deviation increase in exports results in a 0.25 standard deviation increase in the wage gap. Hence, if I account for differences in the variances of the variables, the effect of international trade is comparable to the effect of the structural composition. The effect of technological progress is much smaller compared to international trade and the structural composition. A one standard deviation change in R&D results in a 0.07 standard deviation increase in the wage gap.

Columns (3) and (4) show the results of the fixed-effects regression. Again, a comparison of the unstandardized coefficients can mislead to the interpretation that the effect of structural change on the wage gap is much larger than the effects of international trade and technological progress. But, accounting for differences in the variances of the variables, the effect of international trade becomes even larger than the effect of structural change. A one standard deviation change in the exports results in a 0.4 standard deviation increase in the wage gap, whereas a change in the standard deviation of the structural component only leads to a 0.17 increase in the wage gap. In summary, the results show that it is crucial to account for differences in the variances of variables measured at different levels. After taking this into account, the effect of structural change is still significant and meaningful. But now, it is comparable to the effect of international trade that is now, on the other hand, in line with the literature (see for example OECD (2011)).[44]

Finally, I estimate equation (1) with more aggregated data. In order to check whether

[44]I also estimate the beta coefficients with data on imports instead of exports which confirms the robustness of the results.

the detailed establishment-level data set of the BHP provides additional information on the effects of structural change on the wage gap, I aggregate the micro data to the industry-level and macro-level.[45] For the calculation at the industry-level, all variables are aggregated for each industry at the 3-digit level (according to the classification of economic activities 93 that is included in the BHP) and the 2-digit level (according to the 2-digit ISIC classification of the trade data from the UN comtrade data base):

$$\Delta w_{it} = \alpha + \beta_1 Struc_{it} + \beta_2 Trade_{it} + \beta_3 Tech_{it} + \epsilon_{it}.^{46} \tag{4}$$

The estimated equation at the macro-level looks as follows:

$$\Delta w_t = \alpha + \beta_1 Struc_t + \beta_2 Trade_t + \beta_3 Tech_t + \epsilon_t.^{47} \tag{5}$$

Table 5 presents the results. Column 1 shows the findings concerning the effect of the structural composition at the establishment-level. In this specification, I use the baseline specification as reported in Table 2, column 3 but without including control variables and fixed-effects. The estimation suggests that a 10% increase in the share of employees with tasks in services or administration leads to a 4.9% increase in the wage gap. By aggregating the micro data to the 3-digit industry-level in column 2 (according to equation (4)), the coefficient β_1 remains positive and significant at the 5%-level and becomes even larger than at the establishment-level. With information at the 3-digit industry-level, a 10% increase in the share of employees with occupations in services or administration leads to a 7.5% increase in the difference between the top and the bottom wage quartile. However, at the 3-digit industry-level, the robust standard error increases significantly which leads to a less precise estimation. In addition, the F-statistic of the estimation shows that the regression model is not significant at the 1%-level any more. This points out that the explanatory value

[45] The aggregation should check whether the micro data set provides additional information in contrast to other studies that use sectoral (Blum (2008)) or macro data (OECD (2011)) and thus contributes to the literature by improving the estimated effects of structural change.

[46] The variables are derived in the same way as in equation (4), but they are calculated for each industry i.

[47] Here, Δw_t is the average wage gap over all establishments, $j = 1, ..., n$, in a given year t: $\Delta w_t = \frac{1}{n} \sum_{j=1}^{n} \Delta w_j$ and $Struc_t$ is calculated as the average share of employees with an occupational status "services" or "administration" according to the Blossfeld classification over all establishments in a given year: $Struc_t = \frac{1}{n} \sum_{j=1}^{n} Struc_j$. $Tech_t$ is derived equally. $Trade_t$ is measured as total exports or imports over all industries, $i = 1, ..., k$, in the respective year: $Trade_t = \sum_{i=1}^{k} Trade_i$. In this specification no control variables or fixed-effects are included in the estimation.

Table 5: Estimation with more aggregated data, 1980-2010

	Establishment-Level (1)	Industry-Level (3-digit) (2)	Industry-Level (2-digit) (3)	Macro-Level (4)
Structural Change				
Struc	0.4867***	0.7542**	0.7844**	0.3048
	(0.0047)	(0.3195)	(0.4179)	(4.9547)
Other Controls	No	No	No	No
Industry Fixed Effects	No	No	No	No
Year Fixed Effects	No	No	No	No
Adj. R^2	0.7003	0.7949	0.8850	0.0419
Root MSE	0.4034	0.1241	0.0953	0.9341
Prob > F	0.0000	0.0121	0.1842	0.2538
No. of Obs.	5.3 Mill.	6418	1728	31

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses,
*** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

of the regression model as a whole declines in comparison to the regression at the establishment-level. Column 3 presents the results of the regression at the 2-digit level. Here, the data set is aggregated according to the 2-digit ISIC classification of the trade data from the UN comtrade data base. The estimated coefficient β_1 remains almost constant compared to the regression at the 3-digit level but now, the standard error increases again and the F-statistic shows that the regression model as a whole has no explanatory power any more. Thus, the effect of structural change on the rising wage gap cannot be determined any more. Column 4 shows the results of the regression at the macro-level. Here, all variables are aggregated according to equation (5). Now, the coefficient β_1 is still positive but not significant any more. Furthermore, according to the F-statistic, the model as a whole has no explanatory power.

These results show that the establishment-level data provide important information in comparison to the results at the industry-level or the macro-level. The estimation of the impact of structural change on the rising wage gap at a more aggregated level would bias and/or ignore the distributional effects of the structural reallocation.

The previous approach highlights the importance of establishment-level data by using the same variables as in equation (1) but aggregated to different levels. Next, I compare the wage effects of structural change at the establishment-level with the effects if intra-industry changes are ignored. As mentioned above, the structural reallocation of labor is much more significant after accounting for intra-sectoral changes because there is an increasing number of manufacturers that produce services. Hence, I calculate the structural composition at the establishment-level according to the oc-

cupations that the employees perform. Now, I estimate equation (1) on the basis of the industry classification of the respective establishment. Here, I follow empirical studies at the industry-level (such as Blum (2008)) that have no information about the structural composition of occupations but rather have merely information about employment at the industry-level. Therefore, these studies can only examine inter-sectoral changes since they have to assume that all employees of an industry in the manufacturing sector perform tasks that are related to this sector (and vice versa for the service sector). I also distinguish if industry-level studies have access to further control variables such as the average firm size, the average share of female employees or the average share of high-skilled employees. The results are reported in Table 6:

Table 6: Including versus excluding intra-sectoral changes

	Intra-sectoral changes & inter-sectoral changes	Only inter-sectoral changes			
		Industry-Level (3-digit)		Industry-Level (2-digit)	
	(1)	(2)	(3)	(4)	(5)
Structural Change					
Struc	0.4849***	0.1979	0.5875***	-0.0261	0.1206
	(0.1979)	(0.1551)	(0.1377)	(0.1208)	(0.1157)
Control Variables	Yes	Yes	No	Yes	No
Prob > F	0.0000	0.0000	0.0000	0.0012	0.0012
No. of Obs.	1.87 Mill.	6418	6418	1728	1728

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses,
*** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

Column 1 shows the effect of structural change on the wage gap as it is reported in Table 2. Here, the structural composition is calculated according to the occupations within an establishment. Furthermore, all control variables are derived at the establishment-level. The estimated coefficient accounts for inter-industry and intra-industry changes and is positive and significant. Next, I estimate the wage effects when only inter-industry changes are observed. For that purpose, I assume that all employees of a respective industry[48] perform occupations that are related to

[48]First, I classify the employees according to the 3-digit industry classification of economic activities 93 that is included in the BHP. In a further step, I classify the employment on the basis of the 2-digit ISIC classification of the trade data from the UN comtrade data base.

this industry. Columns 2 and 3 present the results for the estimations at the 3-digit industry level. First, column 2 includes control variables at the industry-level. The estimated wage effect of structural change is still positive but now, it is no longer significant. If the control variables are excluded, column 3 shows that the effect again becomes significant. Hence, if only inter-sectoral changes are considered, it is either not possible to identify an effect of structural change on the wage gap or the data link wage effects to structural change that are in fact caused by other factors that are not included in the regression. Columns 4 and 5 shows the regressions at the 2-digit industry-level. Here, it is not possible to identify an effect of structural change on the wage gap.

To summarize, the results clearly confirm the importance of using establishment-level data that are able to account for intra-sectoral changes of the structural composition of employees. By using these data, I am able to analyze the wage effects of structural change much more precisely than other empirical studies, that only use aggregated industry-level data.

In summary, I obtain strong empirical evidence that structural change is an important cause of the increasing wage inequality in Germany. The effects of international trade and technological progress are also positive and significant which is in line with the common literature on income inequality (e.g. OECD (2011) and Feenstra Hanson (1999)). Moreover, if I account for differences in the variances of the variables using beta coefficients, the effect of structural change on the wage gap is comparable to the positive effects of international trade. By splitting the data set into sub periods and sectors, the estimations provide evidence that the overall wage effect of structural change occurs mainly in the 1990-2010 period and is significantly larger within the manufacturing sector. The comparison with estimations of more aggregated data shows that the detailed establishment-level data set of the BHP provides important information about the effects of structural change on the wage gap. If the impact of the structural reallocation on the wage gap is estimated only at a more aggregated level, the wage effects would be biased or even ignored. In addition, the results clearly show that it is very important to account for intra-industry changes and control for further effects such as the firm size or the share of high-skilled employees. Therefore, this paper contributes to the literature by exposing the considerable impact of structural change on the rising wage gap that so far has been largely ignored.

4.3.2 Robustness Checks

In order to check if my results are robust I estimate the baseline model in various specifications and by different estimation models. The output tables are reported in

the appendix, Table 7 et sqq.
First, I additionally calculate equation (1) by a pooled-ordinary least square specification. The estimations are reported in Table 7, Appendix 4. Without controlling for the structural composition of the economy, column 1 suggests that international trade and technological progress have a positive and significant impact on the increasing wage gap among full-time employees in Germany. If exports or investments in R&D increase by 10%, the wage gap rises by roughly 0.2% or 0.5% respectively.
Taking the structural composition into account, column 2 shows that the coefficients for international trade and technological progress remain constant. This suggests that structural change has an additional effect on the wage distribution that was hidden in the error term before. The effect of the structural component on the wage inequality is positive, highly significant and much larger than the effects of international trade and technological progress. If the share of employees with occupations in services or administration increases by 10%, the wage gap increases by 7.1%.
Column 3 presents the results with an alternative proxy for international trade without controlling for the structural composition. This specification estimates equation (1) with imports to Germany instead of exports from Germany. Column 4 includes the additional impact of the structural change. Both columns provide a robustness check concerning the selection of an indicator regarding international trade. The results confirm the findings of columns 1 and 2.
Second, columns 5 to 12 of Table 7 repeat the estimation strategy form before by using a fixed-effects and a random-effects model respectively. For each model, equation (1) is estimated both with and without *Struc* and with both proxies for international trade. The results confirm the estimations of the pooled-OLS model concerning the effects of structural change, international trade and technological progress although the effects are smaller.
Furthermore, I also estimate a fixed effects specification of equation (1) with clustered standard errors for each industry according to the classification of economic activities 93. The results are reported in Table 8, Appendix 5. The coefficients serve as an additional robustness check and confirm the findings for structural change and technological progress. But now, the coefficients for exports are insignificant.
Next, I also run a fixed-effects regression that controls for regional heterogeneity by including dummies for 16 federal states within Germany. The results, together with selected coefficients of control variables are reported in Table 9, Appendix 6. To compare the results, columns 1 and 2 of Table 9 repeat the estimated coefficients of the fixed-effects estimation of Table 8. Columns 2 and 4 show the results of the same fixed-effects regression but supplemented with regional fixed-effects. All findings con-

firm the previous results. In addition, the coefficients of control variables show that the wage gap increases if an establishment becomes larger, if the share of high-skilled employees increases and if the share of female employment grows. All these effects are in line with the literature.
Finally, I estimate equation (1) only with establishments in Western Germany. By excluding the establishments in Eastern Germany, I am able to check if the effects that I derived so far might be driven by the integration of the Eastern German economy in the course of the German reunification. The results are reported in Table 10, Appendix 7 and show that the estimated coefficients are slightly smaller than in Table 3 but they confirm all previous findings. This provides evidence that the results are not mainly driven by the process of German reunification after 1991. Furthermore, the estimations of Table 10 show that it is sufficient to use a dummy variable to control for the German reunification.
To summarize, the robustness checks confirm the positive effect of the structural composition on the wage gap. The estimated effect is significant and robust across all specifications and estimation models.

5 Conclusion

The current paper examines the impact of structural change, international trade and technological progress on the rising wage gap in Germany and thus puts the focus on an additional cause of the increasing wage inequality that so far has not been explored by the literature. The data confirm that the increasing employment in service occupations leads to an additional skill-bias and therefore changes the labor demand. Taking the growth rates of occupational groups within the service sector into account, the calculations show that not all occupations grow equally but that occupational groups which require the highest qualification levels are characterized by the highest growth rates. Hence, the structural reallocation in Germany works similarly than the effect of technological progress. The stylized facts show that the wage gap in Germany has increased continuously since 1975 which is in line with the findings of many other studies (see for example OECD (2011)). In 2010, the difference between the upper and the lower quartile of the wage distribution was 26% larger than the wage gap in 1975. In addition, the wage gap in the service sector is roughly 21% larger over the whole period. Therefore, an increase of the service sector leads immediately to a larger overall wage gap. Simultaneously, the structural composition of the German economy changed considerably. Taking the occupations of the employees within an establishment into account, the share of services in terms

of employment increased from 52% to almost 70%, whereas the employment in the manufacturing sector declined from 48% to 30%. This structural change is also reflected in the employment of high-skilled and low-skilled employees and in terms of capital accumulation in services and in the manufacturing sector.

In the empirical analysis, I estimate the effects of the structural composition, international trade and technological progress on the wage gap in Germany for the 1980-2010 period. I obtain strong evidence that the structural composition is an important determinant for the rising wage gap in Germany. The effect of the respective coefficient is positive, significant and comparable to the effects of international trade and technological progress. In addition, I show that the effect of structural change cannot easily be identified by using more aggregated data or by excluding intra-sectoral changes of employment.

6 Appendix

Appendix 1: Structure of employees by Blossfeld occupational groups
(**Source:** Blossfeld (1987), Table 1: Classification of occupations)

Name of Occupational Group	**Description of the Occupational Group**	**Examples**
Production		
Agricultural occupations (AGR)	Occupations with a dominant agricultural orientation	Farmers, agricultural workers, gardeners, workers in the forest economy, fishermen
Unskilled manual occupations (EMB)	All manual occupations that showed at least 60 percent unskilled workers in 1970	Miners, rock breakers, paper makers, wood industry occupations, printing industry occupations, welders, unskilled workers, road and railroad construction workers
Skilled manual occupations (QMB)	All manual occupations that showed at most 40 percent unskilled workers in 1970	Glassblowers, bookbinders, typesetters, locksmiths, precision instrument makers, electrical mechanics, coopers, brewers
Technicians (TEC)	All technically trained specialists	Machinery technicians, electrical technicians, construction technicians, mining technicians
Engineers (ING)	Highly trained specialists who solve technical and natural science problems	Construction engineering, electrical engineers, production designers, chemical engineers, physicists, mathematicians

Appendix 1 cont'd:

Name of Occupational Group	Description oth the Occupational Group	Examples
Service		
Unskilled services (EDB)	All unskilled personal services	Cleaners, waiters, servers
Skilled Services (QDB)	Essentially order and security occupations as well as skilled service occupations	Policemen, firemen, locomotive engineers, photographers, hair-dressers
Semiprofessions (SEMI)	Service positions which are characterized by professional specialization	Nurses, educators, elementary school teachers, Kindergarten teachers
Professions (PROF)	All liberal professions and service positions which require a university degree	Dentists, doctors, pharmacists, judges, secondary education teachers, university professors
Administration		
Unskilled commercial and administrational occupations (EVB)	Relatively unskilled office and commerce occupations	Postal occupations, shop assistants, typists
Skilled commercial and administrational occupations (QVB)	Occupations with medium and higher administrative and distributive functions	Credit and financial assistants, foreign trade assistants, data processing operators, book-keepers, goods traffic assistants
Managers (MAN)	Occupations which control factors of production as well as functionaries of organizations	Managers, business administration, deputies, ministers, social organization leaders

Appendix 2: Data Sources and Variables

Variable	Definition	Data Source
Δw	Difference between the top and the bottom quartile of the wage distribution among full-time employees in an establishment (real wages) ($Q_{0.75}$-$Q_{0.25}$)	Establishment History Panel
Struc	**Sectoral Composition:** Share of employees with tasks in services or administration according to Blossfeld occupational groups	Establishment History Panel
Trade	**Integration of the German Economy in International Trade:** Sectoral Export and import data on German manufacturing trade	United Nations Commodity Trade Statistics Data base (UN Comtrade data base)
	Export and import data on German total trade in services	United Nations Conference on Trade and Development Data base (UNCTAD data base)
Tech	**Technological Progress:** Research and Development (R&D) activities of the respective establishment measured by the number of engineers and scientists	Establishment History Panel
X	**Control variables:** Establishment size: Number of full-time employees	Establishment History Panel
	Share of female employment	Establishment History Panel
	Share of high-skilled employees	Establishment History Panel
	German GDP	German Federal Statistical Office
	Education: share of German citizens with post-secondary education	German Federal Statistical Office
	Dummy for German reunification	
Notes:	Before 1991: Fmr. Federal Republic of Germany (Western Germany) All variables are transformed into logarithms.	

Appendix 3: The effect of structural change on the wage gap: Industry-specific regressions

WZ Code	Classification of Economic Activities 1993 (3-digit)	*Struc* - Coefficient
11	Growing of crops; market gardening; horticulture	0.504*** (0.119)
12	Farming of animals	0.789*** (0.149)
13	Growing of crops combined with farming of animals	0.732*** (0.092)
14	Agricultural and animal husbandry service activities	0.525*** (0.138)
20	Forestry, logging and related service activities	0.740** (0.286)
101	Mining and agglomeration of hard coal	0.111 (0.243)
103	Extraction and agglomeration of peat	-0.680 (0.507)
141	Quarrying of stone	0.291 (0.149)
142	Quarrying of sand and clay	0.221 (0.170)
145	Other mining and quarrying n.e.c.	0.975 (0.499)
151	Production, processing and preserving of meat	0.863*** (0.092)
152	Processing and preserving of fish	1.743*** (0.226)
153	Processing and preserving of fruit and vegetables	1.247*** (0.158)
155	Manufacture of dairy products	0.649*** (0.118)
156	Manufacture of grain mill products and starch products	0.638** (0.230)
157	Manufacture of prepared animal feeds	1.171*** (0.305)
158	Manufacture of other food products	0.674*** (0.085)
159	Manufacture of beverages	0.630*** (0.091)
171	Preparation and spinning of textile fibers	1.130** (0.393)
172	Textile weaving	1.227*** (0.142)
173	Finishing of textiles	1.508*** (0.194)
174	Manufacture of made-up textile articles, except apparel	1.592*** (0.195)
175	Manufacture of other textiles	2.018*** (0.203)
176	Manufacture of knitted and crocheted fabrics	1.397*** (0.187)
182	Manufacture of other wearing apparel and accessories	1.084*** (0.171)
183	Dressing and dyeing of fur; manufacture of articles of fur	2.387 (1.502)
192	Manufacture of luggage, handbags and the like	1.144*** (0.288)
193	Manufacture of footwear	1.510*** (0.229)
201	Saw milling and planing of wood; impregnation of wood	1.001*** (0.166)
202	Manufacture of veneer sheets (...) and other panels and boards	1.202*** (0.270)
203	Manufacture of builders' carpentry and joinery	1.084*** (0.157)
204	Manufacture of wooden containers	0.495 (0.295)
205	Manufacture of other products of wood and of articles of cork	0.947*** (0.161)
211	Manufacture of pulp, paper and paperboard	0.929*** (0.166)
212	Manufacture of articles of paper and paperboard	1.089*** (0.105)
221	Publishing	0.979*** (0.099)
222	Printing and service activities related to printing	0.421*** (0.055)
232	Reproduction of recorded media	-0.208 (0.237)
241	Manufacture of basic chemicals	0.478*** (0.103)
243	Manufacture of pesticides and other agro-chemical products	0.802*** (0.132)
244	Manufacture of pharmaceuticals and medicinal chemicals	0.385* (0.170)

Appendix 3 cont'd: Industry-specific regressions

WZ Code	Classification of Economic Activities 1993 (3-digit)	*Struc* - Coefficient
245	Manufacture of soap and detergents (...) and toilet preparations	0.857*** (0.140)
246	Manufacture of other chemical products	0.403* (0.181)
247	Manufacture of man-made fibers	0.524 (0.481)
251	Manufacture of rubber products	0.969*** (0.279)
252	Manufacture of plastic products	1.069*** (0.051)
261	Manufacture of glass and glass products	0.967*** (0.147)
262	Manufacture of (non-)refractory ceramic goods (...)	0.953*** (0.199)
264	Manufacture of bricks, tiles and construction products	2.377*** (0.201)
265	Manufacture of cement, lime and plaster	0.499 (0.283)
266	Manufacture of articles of concrete, plaster and cement	0.825*** (0.107)
267	Cutting, shaping and finishing of stone	0.362 (0.241)
268	Manufacture of other non-metallic mineral products	1.159*** (0.274)
271	Manufacture of basic iron and steel and of ferro-alloys	0.278 (0.187)
272	Manufacture of tubes	0.710** (0.248)
273	Other first processing of iron and steel	1.255*** (0.195)
274	Manufacture of basic precious and non-ferrous metals	0.894*** (0.186)
275	Casting of metals	1.090*** (0.169)
281	Manufacture of structural metal products	0.667*** (0.076)
282	Manufacture of tanks, reservoirs and containers of metal (...)	1.048*** (0.202)
283	Manufacture of steam generators, except central heating	1.261*** (0.241)
284	Forging, pressing, stamping and roll forming of metal	1.512*** (0.188)
285	Treatment and coating of metals; general mechanical engineering	0.637*** (0.120)
286	Manufacture of cutlery, tools and general hardware	1.072*** (0.092)
287	Manufacture of other fabricated metal products	1.024*** (0.079)
291	Manufacture of machinery for the production of mechanical power	1.042*** (0.082)
292	Manufacture of other general purpose machinery	0.365*** (0.079)
293	Manufacture of agricultural and forestry machinery	0.534 (0.376)
294	Manufacture of machine-tools	0.287** (0.088)
295	Manufacture of other special purpose machinery	0.487*** (0.064)
297	Manufacture of domestic appliances n.e.c.	1.284*** (0.203)
300	Manufacture of office machinery and computers	0.759** (0.236)
311	Manufacture of electric motors, generators and transformers	0.524** (0.177)
312	Manufacture of electricity distribution and control apparatus	0.914*** (0.115)
313	Manufacture of insulated wire and cable	1.474*** (0.189)
314	Manufacture of accumulators, primary cells and primary batteries	2.146*** (0.232)
315	Manufacture of lighting equipment and electric lamps	1.090*** (0.150)
316	Manufacture of electrical equipment n.e.c.	0.791*** (0.127)
321	Manufacture of electronic valves and tubes	0.435** (0.145)
322	Manufacture of television and radio transmitters	0.175 (0.129)
323	Manufacture of television and radio receivers (...)	0.424** (0.164)
331	Manufacture of medical and surgical equipment (...)	0.901*** (0.107)
332	Manufacture of instruments and appliances for measuring (...)	0.358*** (0.067)

Appendix 3 cont'd: Industry-specific regressions

WZ Code	Classification of Economic Activities 1993 (3-digit)	*Struc* - Coefficient
333	Manufacture of industrial process control equipment	0.331 (0.206)
334	Manufacture of optical instruments and photographic equipment	0.659*** (0.146)
335	Manufacture of watches and clocks	1.945*** (0.433)
341	Manufacture of motor vehicles	0.169 (0.446)
342	Manufacture of bodies (coachwork) for motor vehicles (...)	1.395*** (0.196)
343	Manufacture of parts and accessories for motor vehicles (...)	1.144*** (0.165)
351	Building and repairing of ships and boats	1.362*** (0.239)
352	Manufacture of railway and tramway locomotives and rolling stock	1.517*** (0.418)
353	Manufacture of aircraft and spacecraft	-0.380 (0.472)
354	Manufacture of motorcycles and bicycles	1.548** (0.556)
355	Manufacture of other transport equipment n.e.c.	0.008 (0.538)
361	Manufacture of furniture	1.436*** (0.086)
362	Manufacture of jewelery and related articles	0.936*** (0.250)
363	Manufacture of musical instruments	0.544 (0.315)
364	Manufacture of sports goods	1.751*** (0.384)
365	Manufacture of games and toys	0.759 (0.436)
366	Miscellaneous manufacturing n.e.c.	0.584*** (0.155)
401	Production and distribution of electricity	0.212* (0.085)
402	Manufacture of gas; distribution of gaseous fuels through mains	-0.026 (0.237)
403	Steam and hot water supply	0.582 (0.411)
451	Site preparation	0.182 (0.151)
452	Building of complete constructions; civil engineering	0.609*** (0.039)
453	Building installation	0.648*** (0.053)
454	Building completion	0.656*** (0.113)
455	Renting of construction or demolition equipment	0.433 (0.319)
501	Sale of motor vehicles	0.349* (0.136)
502	Maintenance and repair of motor vehicles	0.582 (0.411)
503	Sale of motor vehicle parts and accessories	0.748*** (0.173)
504	Sale, maintenance and repair of motorcycles (...)	1.789 (1.119)
505	Retail sale of automotive fuel	-1.218 (0.884)
511	Wholesale an a fee or contract basis	0.206* (0.082)
512	Wholesale of agricultural raw Materials and live animals	0.513** (0.189)
513	Wholesale of food, beverages and tobacco	0.212* (0.099)
514	Wholesale of household goods	0.293*** (0.078)
515	Wholesale of non-agricultural intermediate products (...)	0.637*** (0.081)
516	Wholesale of machinery, equipment and supplies	0.420*** (0.112)
517	Other wholesale	0.220 (0.131)
521	Retail sale in non-specialized stores	-0.433** (0.164)
522	Retail sale of food, beverages and tobacco in specialized stores	-0.158 (0.270)
523	Retail sale of pharmaceutical and medical goods (...)	0.429** (0.139)
524	Other retail sale of new goods in specialized stores	0.276*** (0.074)
525	Retail sale of second-hand goods in stores	1.215 (0.681)

Appendix 3 cont'd: Industry-specific regressions

WZ Code	Classification of Economic Activities 1993 (3-digit)	*Struc* - Coefficient
526	Retail sale not in stores	0.534* (0.255)
527	Repair of personal and household goods	0.593** (0.184)
551	Hotels	0.172 (0.179)
552	Camping sites and other provision of short-stay accommodation	0.929*** (0.238)
553	Restaurants	0.287 (0.152)
554	Bars	-0.324 (0.585)
555	Canteens and catering	0.490 (0.252)
601	Transport via railways	0.139 (0.104)
602	Other land transport	-0.724*** (0.163)
611	Sea and coastal water transport	0.074 (0.202)
612	Inland water transport	1.324*** (0.309)
621	Scheduled air transport	0.993** (0.324)
631	Cargo handling and storage	0.524** (0.169)
632	Other supporting transport activities	-0.006 (0.239)
633	Activities of travel agencies and tour operators (...)	-0.165 (0.423)
634	Activities of other transport agencies	-0.221* (0.109)
641	Post and courier activities	0.496 (0.262)
642	Telecommunications	0.349 (0.180)
651	Monetary intermediation	-1.806*** (0.428)
652	Other financial intermediation	0.729 (1.580)
660	Insurance and pension funding, except compulsory social security	-1.573* (0.632)
671	Activities auxiliary to financial intermediation (...)	1.075 (0.810)
672	Activities auxiliary to insurance and pension funding	0.200 (0.242)
701	Real estate activities with own property	0.234 (0.136)
702	Letting of own property	0.738*** (0.104)
703	Real estate activities an a fee or contract basis	0.458*** (0.099)
711	Renting of automobiles	0.429 (0.406)
712	Renting of other transport equipment	0.714 (0.600)
713	Renting of other machinery and equipment	0.421 (0.235)
714	Renting of personal and household goods n.e.c.	1.080***(0.326)
721	Hardware consultancy	0.122 (0.335)
722	Software consultancy and supply	0.103 (0.115)
723	Data processing	-0.203 (0.223)
725	Maintenance and repair of office machinery	0.622* (0.241)
731	Research and experimental development in natural sciences (...)	0.112 (0.097)
732	Research and experimental development in social sciences	0.173 (0.266)
741	Legal, accounting, book-keeping and auditing activities (...)	0.537*** (0.087)
742	Architectural and engineering activities (...)	-0.028 (0.033)
743	Technical testing and analysis	0.024 (0.120)
744	Advertising	0.129 (0.112)
745	Labour recruitment and provision of personnel	0.257*** (0.052)
746	Investigation and security activities	-0.301 (0.247)

Appendix 3 cont'd: Industry-specific regressions

WZ Code	Classification of Economic Activities 1993 (3-digit)	*Struc* - Coefficient
747	Industrial cleaning	-0.048 (0.147)
748	Miscellaneous business activities n.e.c.	0.207 (0.116)
751	Administration of the State and the economic and social policy (...)	0.143*** (0.033)
752	Provision of services to the community as a whole	0.210 (0.113)
753	Compulsory social security activities	0.504** (0.176)
801	Primary education	-0.840*** (0.213)
802	Secondary education	-0.036 (0.106)
803	Higher education	0.444** (0.169)
804	Adult and other education	0.296*** (0.086)
851	Human health activities	-0.158* (0.064)
852	Veterinary activities	0.123 (0.339)
853	Social work activities	-0.111 (0.069)
900	Sewage and refuse disposal, sanitation and similar activities	-0.152 (0.083)
911	Activities of business, employers' and professional organizations	0.675*** (0.119)
912	Activities of trade unions	2.212 (1.745)
913	Activities of other membership organizations	0.389*** (0.083)
921	Motion picture and video activities	0.654* (0.300)
922	Radio and television activities	0.016 (0.321)
923	Other entertainment activities	0.295 (0.183)
924	News agency activities	-0.708 (0.747)
925	Library, archives, museums and other cultural activities	0.432 (0.274)
926	Sporting activities	0.890** (0.326)
927	Other recreational activities	0.282 (0.329)
930	Other service activities	0.365 (0.188)
950	Private households with employed persons	-2.339 (1.351)
990	Extra-territorial organizations and bodies	0.645** (0.231)

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

32 missing industries due to insufficient observations or confidentiality.

Appendix 4

Table 7: Pooled-OLS, Fixed-Effects and Random-Effects estimation

Variables	Pooled-OLS				Fixed-Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Structural Change								
Struc		0.7147***		0.7146***		0.4778***		0.4781***
		(0.0046)		(0.0046)		(0.0093)		(0.0094)
International trade								
Exports	0.0246***	0.0269***			0.0128***	0.0174***		
	(0.0049)	(0.0049)			(0.0036)	(0.0034)		
Imports			0.0646***	0.0652***			0.0295***	0.0332***
			(0.0038)	(0.0037)			(0.0029)	(0.0029)
Technological Progress								
R&D	0.0476***	0.0488***	0.0475***	0.0487***	0.0209***	0.0153***	0.0207***	0.0151***
	(0.0008)	(0.0008)	(0.0008)	(0.0008)	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.1766	0.1923	0.1767	0.1924	0.7234	0.7257	0.7234	0.7257
No. of Obs.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

Table 7 (cont'd):Pooled-OLS, Fixed-Effects and Random-Effects estimation

Variables	Random-Effects			
	(9)	(10)	(11)	(12)
Structural Change				
Struc		0.5374***		0.5376***
		(0.0119)		(0.0119)
International trade				
Exports	0.0150**	0.0169**		
	(0.0059)	(0.0059)		
Imports			0.0330***	0.0319***
			(0.0052)	(0.0051)
Technological Progress				
R&D	0.0284***	0.0233***	0.0283***	0.0231***
	(0.0020)	(0.0020)	(0.0020)	(0.0020)
Other Controls	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R^2	0.1635	0.1782	0.1636	0.1783
No. of Obs.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients
can be interpreted as elasticities.

Appendix 5

Table 8: Fixed-Effects estimation with clustered standard errors

Variables	Fixed-Effects Regression			
	(1)	(2)	(3)	(4)
Structural Change				
Struc		0.4779***		0.4781***
		(0.0691)		(0.0691)
International trade				
Exports	0.0156	0.0175		
	(0.0152)	(0.0149)		
Imports			0.0320**	0.0332**
			(0.0172)	(0.0173)
Technological Progress				
R&D	0.0209***	0.0152***	0.0207***	0.0150***
	(0.0054)	(0.0057)	(0.0054)	(0.0057)
Other Controls	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adj. R^2	0.7248	0.7257	0.7248	0.7257
Root MSE	0.3504	0.3497	0.3504	0.3497
Prob > F	0.0000	0.0000	0.0000	0.0000
No. of Obs.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients
can be interpreted as elasticities.

Appendix 6

Table 9: Controlling for regional heterogeneity in Germany

Variables	Fixed-Effects Regression			
	(1)	(2)	(3)	(4)
Struc	0.4779***	0.4781***	0.4781***	0.4783***
	(0.0691)	(0.0691)	(0.0692)	(0.0691)
Exports	0.0175		0.0173	
	(0.0149)		(0.0149)	
Imports		0.0332*		0.0331*
		(0.0173)		(0.0173)
R&D	0.0152***	0.0150***	0.0152***	0.0150***
	(0.0057)	(0.0057)	(0.0057)	(0.0057)
Control Variables:				
Establishment Size	0.0594***	0.0593***	0.0590***	0.0588***
	(0.0076)	(0.0075)	(0.0076)	(0.0076)
Share HQ empl.	0.0593***	0.0593***	0.0592***	0.0592***
	(0.0070)	(0.0070)	(0.0071)	(0.0070)
Share female empl.	0.4667***	0.4669***	0.4659***	0.4663***
	(0.0798)	(0.0797)	(0.07994)	(0.0798)
Other Controls	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Regional Fixed Effects	No	No	Yes	Yes
Adj. R^2	0.7248	0.7257	0.7259	0.7259
Root MSE	0.3497	0.3497	0.3495	0.3495
Prob > F	0.0000	0.0000	0.0000	0.0000
No. of Obs.	1.87 Mill.	1.87 Mill.	1.87 Mill.	1.87 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients
can be interpreted as elasticities.

Appendix 7

Table 10: Fixed-Effects estimation (only for Western Germany), 1980-2010

	Overall Effect	Effects in Sub Periods			Effects Within Sectors	
		1980-1990	1990-2000	2000-2010	Manufacturing	Services
	(1)	(2)	(3)	(4)	(5)	(6)
Structural Change						
Struc	0.4585***	0.3916***	0.4037***	0.4119***	0.7776***	0.1282***
	(0.0101)	(0.0238)	(0.0196)	(0.0206)	(0.0141)	(0.0143)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.6850	0.7502	0.7376	0.7532	0.7284	0.6584
Root MSE	0.3416	0.2765	0.3046	0.3219	0.2985	0.3631
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of Obs.	1.55 Mill.	419.335	575.743	660.252	561.868	990.751 Mill.

Dep. Variable: Wage gap ($Q_{0.75}$-$Q_{0.25}$)

Notes: Robust standard errors in parentheses,
*** p<0.01, ** p<0.05, * p<0.1
All variables are logarithms, such that the coefficients can be interpreted as elasticities.

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