Kiel
Working Papers

Kiel Institute
for the World Economy

Offshoring and Labour Market Inequalities

by Tillmann Schwörer

No. 1877 | October 2013

Web: www.ifw-kiel.de

Kiel Institute for the World Economy, Hindenburgufer 66, 24105 Kiel, Germany

Kiel Working Paper No. 1877 | October 2013

Offshoring and Labour Market Inequalities*

Tillmann Schwörer

Abstract:

This paper estimates the effects of offshoring on labour market inequalities between skill groups based on German industry level data from 1995 to 2007. Our main findings are the following: First, offshoring is on average biased in favour of high-skilled employees and in disfavour of low-skilled employees. This effect is strongly driven by the manufacturing sector, material offshoring, and offshoring to Central and Eastern Europe. Second, we find that the labour market adjusts to offshoring mainly through changes in relative wages rather than changes in relative employment. This runs counter to the classical argument that German labour market institutions (collective bargaining, unemployment benefits, etc.) lead to rigid wage structures and high unemployment rates. Third, in the service sector it is the group of medium-skilled employees which is particularly exposed to offshoring, possibly due to the different nature of tasks there. Fourth, medium-skilled employees are also negatively affected by technological change, which explains recent trends towards a polarisation in labour demand.

Keywords: offshoring, skills, labour market, inequalities, seemingly unrelated regression

JEL classification: F14, F66, J23, J24, J31

* Financial support for this research was provided by Fritz Thyssen Stiftung.

Tillmann Schwörer
Kiel Institute for the World Economy
Hindenburgufer 66
24105 Kiel, Germany
Telephone: +49 431 8814573
E-mail: tillmann.schwoerer@ifw-kiel.de

1 Introduction

Labour market inequalities between skilled and less skilled people have widened across the developed world since the 1980s. The United States and the United Kingdom have experienced sharp increases in wage inequalities, while continental Europe has experienced a combination of moderately increasing wage inequalities and/or increasing unemployment rates among the less skilled (e.g. Freeman and Katz, 1995; Nickell and Bell, 1996; Gottschalk and Smeeding, 1997; Machin and van Reenen, 1998; Acemoglu, 2003; OECD, 2011). For the more recent past, several studies have documented a polarisation of employment and/or wages to the detriment of medium skilled labour (e.g. Spitz-Oener, 2006; Goos et al., 2009; Autor and Dorn, 2013).

The forces behind these trends have been subject to extensive research.[1] One strand of the literature has strived to identify determinants of the pervasive growth in labour market inequalities. This literature argues that pervasive market forces – such as offshoring and technological change – have increased the relative demand for skills, over and above the increase in relative skill supply. A second strand of the literature has strived to explain why wage inequalities have grown less in continental Europe than in Anglo-Saxon countries.[2] This literature stresses the role of institutional forces in Europe, such as the broad coverage of collective bargaining, unemployment benefits or high minimum wages, which hold wage inequalities low but cause unemployment among the less skilled.[3] It has therefore been argued that Anglo-Saxon wage inequalities and continental European unemployment are two sides of the same coin (Krugman, 1994).

This paper contributes to both strands of the literature. We provide evidence on changes in labour market inequalities in 28 manufacturing and service industries in Germany between 1995 and 2007, and estimate the explanatory power of offshoring and other demand side factors. We derive our empirical model from a short-run cost function with three types of labour inputs (high, medium, and low skilled workers) which is augmented by offshoring, domestic outsourcing, and technological change. We estimate the resulting system of wage bill share equations using seemingly unrelated regression and instrumental variable regressions. Our analysis builds on a broad empirical literature, including Berman et al. (1994), Feenstra and Hanson (1996b, 1999), Anderton and Brenton (1999), Morrison Paul and Siegel (2001), Eg-

[1] See Katz and Autor (1999) for an overview over the different strands of research in this field.
[2] See Acemoglu (2003) for a summary of the main arguments in this literature.
[3] See for instance Fitzenberger (1999) for Germany.

ger and Egger (2003, 2005), Hijzen et al. (2005), Crinò (2012). However, several new aspects are explored:

First, we allow for heterogeneous effects in the manufacturing sector and the service sector. This enables us to address the hypothesis raised by Blinder (2006, 2009) that low-skilled labour in the service sector is shielded from offshoring, motivated by the fact that low-skilled service jobs are often physically bound to domestic locations. Also, this enables us to address the hypothesis that offshoring and technological change in the service sector lead to polarisation rather than skill bias (see Acemoglu and Autor, 2011; Autor and Dorn, 2013). Second, we analyse whether offshoring affects the labour market through changes in relative wages or through changes in relative employment. In this way we indirectly shed light on the rigidity of wage structures and the role of labour market institutions in Germany. Third, we incorporate several dimensions of offshoring into our estimations that have only recently entered the literature. In particular we distinguish between different types of offshored inputs (materials vs. services) and between different offshoring destinations (China, CEEC, OECD countries, and remaining low-wage countries). Fourth, we reduce problems of omitted variable bias that have been present in many previous studies by controlling for domestic outsourcing.

Our findings can be summarised as follows: Offshoring is on average biased in favour of high skilled labour and in disfavour of low skilled labour. This effect is strongly driven by material offshoring and offshoring to Central and Eastern Europe, and predominantly works through adjustments in relative wages. The latter finding suggests that German wage structures are not as rigid as previous studies suggest. While our main findings hold for the manufacturing sector, we find the opposite direction of bias for the service sector. This finding is in line with the hypothesis that low skilled labour in the service sector is shielded from offshoring by the nature of the tasks they perform. Finally, we also find patterns of polarisation in favour of both high and low skilled labour. However, this pattern is not driven by offshoring but by technological change.

The remainder of this study is structured as follows. Section 2 reviews the theoretical and empirical literature, section 3 describes the data and presents stylized facts on labour market variables and offshoring, section 4 derives the empirical model and discusses our econometric implementation, section 5 presents the econometric results, and section 6 concludes.

2 Literature review

Theoretically, the hypothesis that offshoring raises the relative demand for high skilled labour is grounded on the assumption that firms in the developed "North" offshore their low-skill intensive stages of production (or tasks) to the less-developed "South". This assumption can be rationalised in two different ways. First, in a world where factor price equalisation fails to hold (e.g. because of the presence of non-tradable goods), the relative wage of low skilled labour is smaller in the South than in the North due to its relatively abundance in low skilled labour. This allows firms in the North to arbitrage on factor price differences by offshoring low-skill intensive tasks to the South (e.g. Feenstra and Hanson, 1996a; Deardorff, 2001; Kohler, 2004).

Second, the level of offshoring costs likely differs depending on the nature of the offshored tasks. In particular, researchers have argued that offshoring is relatively cheap if tasks are routine and codifiable and if they can be carried out without physical presence at some location or without face-to-face contact with customers (Leamer and Storper, 2001; Autor et al., 2003; Blinder, 2006, 2009). The criteria of routineness and codifiability are arguably more often satisfied in case of low skilled labour such that the immediate offshoring threat may indeed be larger for this group. Yet, some recent studies have argued that this simple relation between skills and offshorability does not hold in the service sector (Blinder, 2006, 2009; Acemoglu and Autor, 2011; Autor and Dorn, 2013). Jobs of low skilled labour in the service sector are often physically bound to a location and therefore cannot be offshored. Instead, these studies argue that the wave of computerization has exposed medium skilled labour in the service sector to offshoring and automation, thus contributing to a polarisation in employment and wages.

While it is evident that offshoring causes immediate job losses which may be concentrated among particular skill groups, it is less evident how these skill groups are affected in general equilibrium. According to the seminal work by Feenstra and Hanson (1996a,b, 1999) the effect of offshoring on the relative wages of low skilled labour is unambiguously negative. In their model the US offshores production stages to Mexico which are perceived as low-skill intensive in the US and as high-skill intensive in Mexico, due to differences in their levels of economic development. Under this assumption offshoring increases the relative demand and, consequently, the relative wages of high skilled labour in both countries. In this sense outsourcing operates in the same way as a skill-biased technical change that occurs simultaneously in both countries (Kohler, 2001).

The later theoretical literature has shown that under less restrictive assumptions the effects are more ambiguous.[4] If one allows for outsourcing in more than one final good sector then, as Jones and Kierzkowski (2001) put it, "almost anything can happen". In Grossman and Rossi-Hansberg (2008) this ambiguity is given by three partly opposing effects: Low skilled labour suffers from negative labour-supply and relative-price effects but gains from a positive productivity effect.[5] Depending on the relative size of these effects, wages of low skilled labour may fall or rise.

Empirically, there has been much support on the hypothesis that offshoring is skill biased.[6] Early evidence on the United States (Feenstra and Hanson, 1996a, 1999) and the United Kingdom (Anderton and Brenton, 1999) shows that offshoring can explain between 10 and 50% of the increase in the wage bill shares of high skilled labour in the 1970s and 1980s. Later studies extend the analysis to more than two skill-groups. Morrison Paul and Siegel (2001) distinguish four skill groups for the US and find that the lowest two groups are negatively affected and the highest group is positively affected, though offshoring has a smaller impact than technological change. Hijzen et al. (2005) distinguish between three skill groups for the UK and find negative effects for low skilled labour but no significant effects for medium and high skilled labour. Crinò (2010, 2012) and Geishecker and Görg (2013) show that the skill-bias also applies in case of service offshoring.

With respect to Europe there exists similar evidence for France (Strauss-Kahn, 2004), Spain (Minondo and Rubert, 2006), Italy (Helg and Tajoli, 2005), Austria (Egger and Egger, 2003, 2005; Lorentowicz et al., 2008) and Sweden (Ekholm and Hakkala, 2006). Note, however, that many of these studies model the employment effects of offshoring and neglect potential wage effects, thus potentially underestimating the overall impact of offshoring.[7] Turning to Germany, early evidence by Falk and Koebel (2002) shows that offshoring between 1978 and 1990 has negatively affected the demand for low skilled labour, whereas the effects for medium and high skilled labour are not statistically significant. Geishecker (2006) finds that offshoring to Central and Eastern Europe (CEEC) between 1991 and 2000 explains about half of the decline in the wage bill shares of low skilled labour. Schöller

[4]See for instance Arndt (1997) for positive effects for (low skilled) labour, and Venables (1999), Deardorff (2001), Jones and Kierzkowski (2001), Kohler (2004), Grossman and Rossi-Hansberg (2008) for ambiguous effects.

[5]Empirically, productivity effects of offshoring have been identified by Görg and Hanley (2005), Egger and Egger (2006), Görg et al. (2008), Amiti and Wei (2009), and Schwörer (2013).

[6]See Crinò (2009) for a survey of the empirical literature.

[7]See section 4.1.

(2007) is the first to analyse the effects of service offshoring. She finds a negative impact of service offshoring for low skilled labour. Becker et al. (2013) analyse effects on the workforce composition in German multinational enterprises between 1998 and 2001. They find that offshoring causes a shift in favour of high skilled labour and in favour of non-routine and interactive tasks, but not in case of offshoring to CEEC. Baumgarten et al. (2013) analyse individual level data for the period 1991 to 2006 and allow for mobility of workers between industries within occupations. They find that offshoring has an even larger negative impact on wages of low skilled workers if such cross industry effects are taken into account.

To the best of our knowledge, non of these studies has empirically addressed the hypothesis that offshoring has heterogeneous effects in the manufacturing sector vis-à-vis the service sector, and non of these studies has analysed whether the labour market adjusts to offshoring through changes in relative wages or changes in relative employment.

3 Data, measurement, and stylized facts

3.1 Data and measurement

This paper uses industry-level data for Germany in the period 1995 to 2007. The sample comprises 14 manufacturing industries (NACE revision 1 codes 15-37) and 14 service industries (40-74) mainly measured at the 2-digit level.[8] From the EUKLEMS database we retrieve information on wage bills, total hours worked, and number of employees. The first two of these variables can be decomposed into the shares contributed by high, medium, and low skilled labour. To obtain a corresponding decomposition for the number of employees we use additional data from the Labour Force Survey (LFS) of the European Union. Offshoring variables are based on data from the World Input Output Database (WIOD) as in Schwörer (2013). WIOD contains information on the value of material and service inputs used by German industries and on the source countries from which these inputs are obtained. This study defines offshoring (OS) of industry j in year t as the share of imported inputs (M) from all 28 industries ($i = 1, \ldots, I$) and all countries ($c = 1, \ldots, C$) in output (Y):

[8] The level of industry aggregation and the sample period are dictated by the main data sources used, EUKLEMS and WIOD. The sample period ends in 2007 since more recent data for several variables are only available for the NACE revision 2 industry classification, which cannot accurately be harmonized at the 2-digit level with NACE revision 1.

$$OS_{jt} = \frac{\sum_{i=1}^{I}\sum_{c=1}^{C} M_{ic,jt}}{Y_{jt}} \tag{1}$$

OS is similar to the well-known broad offshoring measure introduced by Feenstra and Hanson (1996b) but differs in three ways: 1. *OS* comprises service offshoring in addition to material offshoring. 2. Imports are scaled by output rather than non-energy inputs. This scaling is important for our econometric analysis because it allows us (jointly with the fact that we control for domestic outsourcing) to identify how offshoring of inhouse production affects relative skill demand. We thereby avoid confounding offshoring of inhouse production with the substitution of domestic suppliers by foreign suppliers.[9] 3. We directly obtain industry-specific imports ($M_{ic,jt}$) from WIOD, whereas Feenstra and Hanson derive them from domestic input-output tables based on a restrictive proportionality assumption for imports.[10] But note that WIOD data are themselves based on a similar, though less restrictive, type of proportionality assumption (Timmer et al., 2012).

We complement this broad offshoring measure with more detailed measures by restricting the range of imports: First, we distinguish between offshoring to Central and Eastern European countries (CEEC), China, OECD countries (excluding CEEC), and the rest of the world (RoW). Second, we distinguish between material offshoring and service offshoring.[11] Third, we define domestic outsourcing (*DO*) as the share of domestic inputs in output, in complete analogy to the broad offshoring measure.

3.2 Stylized facts on the labour market and offshoring

At the aggregate level the share of high skilled employment in total employment has grown by $\Delta S_H = 3.8\%$ between 1995 and 2007. As a first step towards an explanation of this fact, we assess to which extent this is due to employment shifts between industries or to growing skill-intensities within industries. Berman et al. (1994) introduced this analysis to discriminate between a Stolper-Samuelson type explanation, which would require employment shifts towards skill-intensive indus-

[9] See section 4.2 as well as Schwörer (2013) and Castellani et al. (2013) for more details.

[10] This proportionality assumption has been criticised as highly restrictive by Feenstra and Jensen (2012), Puzzello (2012), and Winkler and Milberg (2009).

[11] For instance, offshoring to China is defined as the share of (material and service) imports from China in output. Similarly, service offshoring is defined as the share of service imports (from all countries) in output.

tries,[12] and an explanation based on technological change, which would require increasing skill intensities within industries. As pointed out by, e.g., Feenstra and Hanson (1996a) the effects of offshoring are from a theoretical point of view akin to skill-biased technological change. Hence, the within-industry component captures offshoring as well as technological change as potential sources of the aggregate trend. Following Berman et al. (1994) the decomposition is given by

$$\Delta S_H = \sum_j \Delta F_j \bar{S}_{Hj} + \sum_j \Delta S_{Hj} \bar{F}_j \tag{2}$$

where S_{Hj} is the employment share of high skilled labour in industry j, F_j is the fraction of industry j in aggregate employment, Δ denotes the change in variables between 1995 and 2007, and bars denote time averages. The first term on the right hand side captures the contribution of between-industry shifts and the second term captures the contribution of within-industry shifts.

Our decomposition shows that 69% of the aggregate growth in the share of high skilled employment is due to within-industry shifts and 31% is due to between-industry shifts. Similar numbers are obtained when we decompose the employment shares of medium (66 vs. 34%) or low skilled labour (78 vs. 22%).[13] The decomposition suggests that factors such as offshoring and technological change, which may affect skill-intensities within industries, may have indeed more explanatory power than trade in final goods according to the Stolper-Samuelson theorem. Before turning to the econometric analysis of the link between offshoring and relative labour demand, we document some more stylized facts.

Table 1 summarizes trends in labour market outcomes by skill group. The numbers represent aggregate changes between 1995 and 2007 in %. We observe that the wage bill of high skilled labour has increased by 38%, whereas the wage bill of medium and low skilled labour has increased by only about 4% each. The wage bill share can be further decomposed into three components: number of employees, hours worked per employee, and the hourly wage rate. In terms of employment we observe the largest growth rates for high skilled labour, the second largest growth rate for low skilled labour, and the smallest growth rate for medium skilled labour.

[12] According to the Stolper-Samuelson theorem, growing import competition from low-skill abundant countries would cause further specialisation of high-skill abundant countries such as Germany on high-skill intensive goods. By implication, we should observe employment shifts between industries towards the high-skill intensive industries.

[13] The numbers are in line with evidence on the 1980s and 1990s by Christensen and Schimmelpfennig (1998) and Geishecker (2006).

Table 1: Aggregate changes in labour market outcomes by skill group (1995-2007; %)

	High	Medium	Low
Wage bill	37.72	3.94	4.34
Number of employees	11.21	1.41	5.33
Hours worked per employee	6.71	-8.39	-13.11
Hourly wage	16.04	11.84	14.04

This table shows the aggregate growth rates between 1995 and 2007 of labour market outcomes by skill group (in %). For instance, the upper-left element means that the wage bill of high skilled labour has increased between 1995 and 2007 by 37.72%. Note that by definition the wage bill can be written as the product of the other three variables.

In terms of the hourly wage a similar though somewhat weaker pattern applies.[14] In terms of the hours worked we observe a clear linear bias in favour of higher skilled labour. Medium and low skilled labour has even reduced the average working time.

Table 2 replicates the stylized facts of table 1 for the manufacturing sector and the service sector individually. We observe that total employment has fallen in the manufacturing sector and has grown in the service sector. Beyond this general pattern there are some remarkable differences between the two sectors with respect to skill-specific trends. In the manufacturing sector there is a clear linear bias in favour of more skilled labour. The highest growth rates of employment, hours worked, and wages are observed for high skilled labour and the lowest growth rates are observed for low skilled labour. In the service sector there is larger heterogeneity in the evolution of employment, hours worked and wages, but overall a distinctive pattern of polarisation in favour of high and low skilled labour. In terms of the number of employees the highest growth rate is observed for high skilled labour but the growth rate for low skilled labour is only slightly smaller. In terms of wages we even observe the highest growth rate for low skilled labour. Only in terms of hours worked we observe a different pattern. Here low skilled labour has the smallest growth rate.

Next, we document in table 3 stylized facts on the evolution of offshoring, domestic outsourcing, and inhouse production between 1995 and 2007. This is essentially a decomposition exercise as each variable is scaled by output. Any increase in offshoring is therefore, by construction, mirrored by a corresponding decrease in inhouse production or domestic outsourcing. This type of decomposition is useful because it reveals to which extent offshoring replaces inhouse production (we may

[14] The previous evidence on wage inequalities in Germany is mixed. Several studies have highlighted the stability of Germany's wage dispersion (Abraham and Houseman, 1995; Freeman and Schettkat, 2001; Prasad, 2004). By contrast, recent studies provide evidence of growing wage inequalities since the 1980s and even an acceleration of this trend in the mid-1990s (Dustmann et al., 2009; OECD, 2011; Card et al., 2013).

Table 2: Changes in labour market outcomes by skill group and main economic sector (1995-2007;%)

	Manufacturing sector			Service sector		
	High	Medium	Low	High	Medium	Low
Wage bill	37.60	3.46	-17.46	37.78	4.21	24.91
Number of employees	-8.68	-8.99	-18.01	21.32	6.12	19.53
Hours worked per employee	12.73	-7.54	-12.65	4.01	-8.79	-13.27
Hourly wage	33.64	22.98	15.28	9.20	7.61	20.50

This table shows the aggregate growth rates between 1995 and 2007 of labour market outcomes by skill group and by main economic sector (in %). For instance, the upper-left element means that the wage bill of high skilled labour in the manufacturing sector has increased between 1995 and 2007 by 37.60%. Note that by definition the wage bill can be written as the product of the other three variables.

Table 3: Aggregate changes in offshoring, domestic outsourcing, and inhouse production (1995-2007)

	Total			Manufacturing			Services		
	1995	2007	Δ%	1995	2007	Δ%	1995	2007	Δ%
Inhouse production	49.83	44.90	-10%	36.48	30.95	-15%	59.01	56.27	-5%
Domestic outsourcing	40.17	38.83	-3%	46.96	42.66	-9%	35.50	35.70	1%
Offshoring	7.37	13.10	78%	13.05	22.17	70%	3.46	5.71	65%
… of materials	5.34	9.07	70%	10.38	17.16	65%	1.88	2.47	31%
… of services	1.40	2.62	87%	1.38	2.31	67%	1.41	2.87	104%
… to OECD countries	5.28	7.68	45%	9.35	12.65	35%	2.48	3.63	46%
… to CEEC	0.51	1.61	216%	0.87	2.89	232%	0.26	0.56	115%
… to China	0.28	1.00	257%	0.44	1.60	264%	0.17	0.50	194%
… to RoW	1.30	2.82	172%	2.39	5.03	110%	0.56	1.02	82%

This table shows aggregate changes between 1995 and 2007 in inhouse production, domestic outsourcing, and offshoring. Variables are scaled by output and written in %. E.g., the upper-left elements mean that the share of inhouse production in output has changed from 49.83% in 1995 to 44.90% in 2007, which implies a decline by 10%. Note that the fourth component of total output (taxes, subsidies, and international transport margins) is not reported. Similarly, offshoring of primary inputs (NACE 1-14) and of some remaining services (NACE 80-95) are not reported.

call this "genuine offshoring") and to which extent offshoring replaces domestic outsourcing (this reflects supplier changes).[15]

Columns 1-3 show aggregate trends between 1995 and 2007 including both the manufacturing and the service sector: inhouse production declined from about 50 to 45% of output which implies a decline by 5 percentage points (ppt) or 10%, domestic outsourcing declined by 1.3 ppt (-3%), and offshoring increased by 5.7 ppt (+78%). This suggests that Germany has experienced substantial relocations of inhouse production to foreign suppliers and – by a smaller scale – substitution of domestic suppliers by foreign suppliers. Furthermore, we observe that material offshoring accounts for a large part of total offshoring, though the growth rate is higher for service offshoring. Similarly, we observe that OECD countries represent the most important group of offshoring destinations, though the growth rates for

[15] The importance of such a broad account of the changes in the organization of production has been highlighted in Winkler (2010), Castellani et al. (2013), and Schwörer (2013).

Central and Eastern European countries, China, and the mostly low-wage "rest of the world" are considerably higher.

Columns 4-6 and 7-9 prove that the main aggregate pattern – reduced inhouse production and increased offshoring – applies also for the manufacturing sector and the service sector individually. However, we observe that the service sector offshores considerably less than the manufacturing sector (5.7% vs. 22.1% in 2007). During the sample period, offshoring increased in the service sector by 2.3 ppt and in the manufacturing sector by 9.1 ppt. This suggests that the scope for distributional effects of offshoring should be larger in the manufacturing sector.

From the summary statistics and the existing literature we condense several research questions that shall be addressed in the econometric analysis below: Can the observed increase in the relative demand for high skilled labour be explained by changes in offshoring or technologies? Does offshoring or technological change explain the differences in labour market trends between the manufacturing and the service sector, and in particular the trend towards polarisation in the service sector? Do offshoring destinations or the type of offshored inputs matter for these effects? Against the background of German labour market institutions: does the labour market adjust to offshoring through changes in relative wages or through changes in relative employment rates?

4 Empirical model

4.1 Derivation of the empirical model

We analyse these questions econometrically by estimating a system of three wage bill share equations, which we derive from an industry cost function augmented by offshoring. Similar models have been used in the context of trade and offshoring by a large number of studies.[16] We proceed as follows. First, we briefly describe the most widely used empirical model in the literature. Second, we describe modifications of this benchmark model which have been used in studies on continental Europe to account for wage rigidities. Third, we show how variations of the benchmark model can be used to identify whether offshoring affects the relative demand for skills through changes in relative wages or relative employment.

[16]This model was first proposed in the context of trade by Berman et al. (1993, 1994) and in the context of offshoring by Feenstra and Hanson (1996b). See Crinò (2009) for a review of the empirical literature.

We start with an arbitrary industry short-run cost function[17]

$$C(\mathbf{W},K,Y,\mathbf{Z}) = \min_{\mathbf{E}}(\mathbf{W}'\mathbf{E}) \quad \text{subject to} \quad Y = f(\mathbf{E},K,\mathbf{Z}) \tag{3}$$

where $\boldsymbol{W}$ is a vector of wages for high (H), medium (M), and low (L) skilled labour, and $\boldsymbol{E}$ is the corresponding vector of labour inputs. Industry and time subscripts are omitted to simplify notation. K denotes capital input, Y denotes output, and $\boldsymbol{Z}$ is a vector of shift factors that includes offshoring, domestic outsourcing and technological change. These shift factors may have two different types of effects. First, they can reduce the labour input requirements for the production of a given output (productivity effect). Second, they can change the cost efficient skill mix (distributional effect or factor bias effect). In this study we are interested in the latter type of effect.

The cost function can be approximated using the translog function[18]

$$\begin{aligned}
\ln C(\mathbf{W},K,Y,\mathbf{Z}) =& \alpha + \sum_{s\in S}\beta_s \ln W_s + \frac{1}{2}\sum_{s\in S}\sum_{t\in S}\gamma_{st}\ln W_s \ln W_t + \beta_k \ln K + \gamma_{KK}\ln K^2 \\
&+ \beta_Y \ln Y + \gamma_{YY}\ln Y^2 + \sum_{p\in P}\beta_p Z_p + \frac{1}{2}\sum_{q\in Q}\gamma_{pq} Z_p Z_q \\
&+ \sum_{s\in S}\gamma_{sK}\ln W_s \ln K + \sum_{s\in S}\gamma_{sY}\ln W_s \ln Y + \sum_{s\in S}\sum_{p\in P}\gamma_{sp} Z_p \ln W_s \\
&+ \gamma_{KY}\ln K \ln Y + \sum_{p\in P}\gamma_{Kp} Z_p \ln K + \sum_{p\in P}\gamma_{Yp} Z_p \ln Y
\end{aligned} \tag{4}$$

where indices s and t represent skill levels and indices p and q represent shift variables. Differentiating with respect to the log wage of skill group s we obtain

$$\frac{\ln C}{\ln W_s} = \beta_s + \sum_{t\in S}\gamma_{st}\ln W_t + \gamma_{sK}\ln K + \gamma_{sY}\ln Y + \sum_{p\in P}\gamma_{sp} Z_p \tag{5}$$

Using Shephard's Lemma[19] it follows that the left hand side of equation 5 is the

[17]The cost function short-run because we do not observe industry-specific capital prices and therefore assume that capital is quasi-fixed. The short-run costs are, thus, given by the industry's wage bill ($\mathbf{W}'\mathbf{E}^*$).

[18]The translog function is particularly suited because the functional form is highly flexible. According to Greene (2002) the translog cost function is the most popular specification in empirical work. Alternatives that have been used in the literature include the Leontief cost function (Morrison Paul and Siegel, 2001) and the Box-Cox cost function (Falk and Koebel, 2002).

[19] $\frac{\partial C}{\partial W_s} = E_s^*$, where E_s^* is the cost efficient labour input of skill group s.

wage bill share (*WSH*) of skill group *s*:

$$\frac{\ln C}{\ln W_s} = \frac{\partial C/C}{\partial W_s/W_s} = \frac{\partial C}{\partial W_s}\frac{W_s}{C} = \frac{E_s^* W_s}{C} \equiv WSH_s \tag{6}$$

We obtain the following system of wage bill share equations:

$$WSH_H = \beta_H + \sum_{t \in S} \gamma_{Ht} \ln W_t + \gamma_{HK} \ln K + \gamma_{HY} \ln Y + \sum_{p \in P} \gamma_{Hp} Z_p C \tag{7}$$

$$WSH_M = \beta_M + \sum_{t \in S} \gamma_{Mt} \ln W_t + \gamma_{MK} \ln K + \gamma_{MY} \ln Y + \sum_{p \in P} \gamma_{Mp} Z_p C \tag{8}$$

$$WSH_L = \beta_L + \sum_{t \in S} \gamma_{Lt} \ln W_t + \gamma_{LK} \ln K + \gamma_{LY} \ln Y + \sum_{p \in P} \gamma_{Lp} Z_p C \tag{9}$$

Variants of this "benchmark model" have been estimated by a large number of studies (see Crinò 2009 for a survey). In the following we discuss a critical property of this model, which may likely cause an underestimation of the skill bias induced by offshoring or technological change: In equations 7 - 9 the offshoring coefficients capture the effects on the wage bill share of skill group *s* conditional on the wages of high, medium, and low skilled labour (and other covariates). Since the wage bill share is a function of wages and employment, the effect of offshoring on wages is completely absorbed by the wage controls and only the effects on relative employment is retained. We argue that this property is problematic because it entails an underestimation of the skill bias except for the unlikely case that wages are exogenous to changes in offshoring. In the more likely case at least some of the laid off workers are reabsorbed by the same industry at a lower wage. We therefore believe that the narrow focus on relative employment effects implied by the benchmark model is not well suited to capture the full effects of offshoring. This argument is of particular relevance for countries characterised by flexible wages, such as the US and UK. However, in light of the explicit evidence on wage effects due to offshoring (Geishecker and Görg, 2008; Baumgarten et al., 2013) the argument is also likely to extend to continental Europe.[20]

Surprisingly, several studies on continental Europe use the alleged presence of wage rigidities to justify the choice of a different empirical model, which replaces the wage bill shares by employment shares.[21] Strauss-Kahn (2004), e.g., motivates

[20]Recall also that this strand of the offshoring literature has emerged precisely because traditional trade theory failed to explain the growing wage inequalities. Thus, it seems inappropriate to estimate models which, by construction, cannot explain these effects either.

[21]See, for instance, Egger and Egger (2003), Strauss-Kahn (2004), Helg and Tajoli (2005), and in a

this approach in the following way: "Although it could be argued that one should focus on the change in the relative wages [...], I believe that changes in employment shares is the more appropriate variable to analyze in considering the French case. Over the past three decades the French earnings dispersion between skilled and unskilled workers did not significantly rise, whereas France's employment share of skilled workers increased dramatically. This behavior of relative wages is common to most continental European countries and differs greatly from the U.K. and U.S. experience." Again, our major objection to this approach is that it assumes away rather than tests for potential effects on relative wages. Geishecker (2006) follows a different strategy. Using a C-Test he shows that wages can be treated as exogenous variables, which allows him to estimate the benchmark model without bias. However, given the functional relationship between wage bill shares and wages, the result of this exogeneity test is surprising. Ekholm and Hakkala (2006) and Crinò (2012) use yet another strategy. Estimating wage bill share equations they exclude the wage regressors in a robustness check, and conclude that their previous results are robust to this exclusion.

In this study we proceed in a similar way as Ekholm and Hakkala (2006) and Crinò (2012). However, we interpret this not as a robustness check, but as a way to identify whether offshoring affects the labour market through changes in relative wage or through changes in relative employment: First, in our main specification we estimate a wage bill share equation that excludes wage regressors. Thereby we aim to capture the total effect of offshoring on the wage bill shares, capturing both the wage channel and the employment channel.[22] Second, we estimate a wage bill share equation that includes wage regressors. Thereby we aim to capture the effects of offshoring on the wage bill shares which operate through the employment channel.

4.2 Econometric implementation

Several remarks on the econometric implementation are indicated at this point. First, we specify the variables in the estimation model as follows:

- Wage bill shares (*WSH*), logged wages by skill group (W_H, W_M, W_L), and logged output (Y) are directly obtained from the EUKLEMS database. Capi-

robustness check Lorentowicz et al. (2008).

[22]Note that this is essentially the model estimated by Feenstra and Hanson (1996b, 1999) (on offshoring) and Machin and van Reenen (1998) (on technological change).

tal is measured as logged share of capital stock in output (*KInt*).

- Technological change is captured through two different variables: the share of research and development expenditures in total expenditures (*R&D*) and the share of investments in information and communication technologies in total investment (*ICT*).

- In the baseline specifications we use a broad offshoring measure (*OS*) that captures imports of all inputs (i.e. from NACE industries 15-74) and all countries. In later specifications we include separate measures for offshoring to Central and Eastern Europe, China, OECD, and the rest of the World; or separate measure for offshoring of material inputs and service inputs (see also section 3.1). All specifications also use a broad measure for domestic outsourcing (*DO*).

- Year fixed effects are included to account for changes in the relative supply of skills and other time-varying macroeconomic factors.

Second, to account for unobserved industry-specific time-variant factors that may be correlated with offshoring we use a fixed effects estimator. This implies that our inference is based on the variation of variables within sectors. Also, we account for clustering of standard errors within industries.

Third, endogeneity problems may arise either if variables, which are correlated with offshoring, are omitted from the regression (omitted variable bias) or if offshoring is endogenous due to simultaneity of the offshoring decision and the skill demand decision (simultaneity bias). We deal with the first issue by jointly controlling for two measures of technological change and by controlling for domestic outsourcing. Winkler (2010), Schwörer (2013), and Castellani et al. (2013) have shown that the latter is important in order to avoid mixing up offshoring of inhouse production with changes in supplier structures.[23]

To deal with a possible simultaneity bias we apply instrumental variable estimations using current and lagged offshoring intensities of Austria and France as instruments for offshoring in Germany. We expect these instruments to be correlated with the endogenous regressor since trade and communication costs declined in all three countries in a similar way and also since their geographical location

[23]Note that the following identity holds: offshoring + domestic outsourcing + inhouse production = 100%. Hence, if domestic outsourcing is controlled for in the regression, any increase in offshoring is mirrored by a decrease in inhouse production. In this way one can unambiguously identify whether offshoring of inhouse production changes the relative skill mix.

provides the countries with access to the same offshoring destinations. At the same time our instruments should be valid instruments if offshoring in Austria and France is unrelated to the relative demand for skills in Germany (other than through the correlation in offshoring). Arguably, there are factors which jointly affect offshoring in Austria and France and the demand for skills in Germany. For instance, it is reasonable to believe that the invention of the internet has increased the scope for offshoring around the globe and at the same time increased the relative demand for skilled labour in Germany. Thus, in order for our instruments to be valid we need to control for such factors. We believe that through the inclusion of two proxies for technological change and the inclusion of year fixed effects we are able to control for the most important sources of bias. We test for the reliability and validity of our instruments, as detailed in the section 5.

Four, we estimate the system of equations using seemingly unrelated regression (SUREG), which is a generalized least squares estimator. SUREG has been used in the same context by e.g. Hijzen et al. (2005), Ekholm and Hakkala (2006), and Crinò (2012). Different from equation-by-equation OLS, SUREG allows for correlation of the error terms across equations. According to Greene (2002) the coefficient estimates and standard errors from SUREG and equation-by-equation OLS are identical except a) if the equations have different sets of regressors or b) if parameter constraints are imposed. In our model the regressors are identical in the equations for high, medium, and low skilled labour. Still, SUREG is useful for our purposes because it allows us to test for differences in parameters across equations. Moreover, specific parameter constraints may be warranted in the model with wage controls to ensure that the estimated model satisfies the properties of the underlying cost function. For instance, symmetry requires $\gamma_{st} = \gamma_{ts}$ for all $t, s = [H, M, L]$.[24] In robustness checks we impose these and other constraints on the wage coefficients (see section 5.3).

Note that only two of the three equations are linearly independent because the wage bill shares of high, medium, and low skilled labour sum to 1. Since SUREG is only feasible for linearly independent equations we have to drop one equation. The results are invariant to our choice of the equation to be dropped, precisely because in our case SUREG is equivalent to equation-by-equation OLS. This fact allows us to easily obtain the coefficients of *all* equations and to perform *all* cross-equation

[24]This means, e.g., that an increase in the wage of high skilled labour affects the wage bill share of low skilled labour (γ_{HL}) in the same way as an increase in the wage of low skilled labour affects the wage bill share of high skilled labour (γ_{LH}).

tests on differences in coefficients, by separately estimating SUREG for each pair of equations (i.e. we estimate SUREG three times).[25] Different than many previous studies we estimate SUREG by maximum likelihood rather than iterating Zellner's method, which allows us to estimate cluster-robust standard errors.[26] Maximum likelihood estimation is also helpful for the robustness check with imposed symmetry constraints, because it ensures that results are invariant to the choice of the equation to be dropped (Berndt, 1991, p. 473).

5 Econometric results

5.1 Baseline results

This section reports and discusses the econometric results. Table 4 shows the baseline results obtained from fixed effects (FE) seemingly unrelated regressions (SUREG) of the system of equations described in section 4.1. Dependent variables of the three equations are the wage bill shares of high, medium, and low skilled labour. The number of observations (364) is given by the number of industries (28) times the number of years (13). Time dummies are included but coefficients are not reported to save on space. Cluster-robust standard errors are reported in parantheses.

In specification (1) the system is estimated without wage controls. As discussed in section 4.1 we thereby aim to capture the total effect of offshoring on the wage bill shares, capturing both the wage and employment channel. We observe that industry size, measured by industry output, is negatively linked with the wage bill share of high skilled workers and positively linked with the wage bill share of low skilled workers (statistically significant at the p=5% level). Capital intensity is not statistically significant in all three equations. This means that systematic complementarities between capital and particular skill groups are not observed.

Turning to the shift variables we observe that investment in information and communication technologies (ICT) is negatively associated with medium skilled labour (p=1%) and positively, though statistically insignificantly, associated with

[25] Alternatively, the coefficients and standard errors of the dropped equation could be calculated as a linear combination of the coefficients and standard errors of the directly estimated equations (Berndt, 1991).

[26] Maximum likelihood SUREG is estimated using the STATA ado file mysureg, downloadable from http://www.stata-press.com/data/ml2.html as part of the ml_ado package, and described in Gould et al. (2003).

Table 4: Baseline estimations (SUREG fixed effects model)

	(1)			(2)		
	High	Medium	Low	High	Medium	Low
Y	-0.0289***	0.0005	0.0284***	-0.0209***	0.0026	0.0183***
	(0.0085)	(0.0035)	(0.0079)	(0.0067)	(0.0047)	(0.0062)
KInt	-0.0127	-0.0009	0.0137	-0.0043	0.0049	-0.0006
	(0.0129)	(0.0072)	(0.0147)	(0.0102)	(0.0075)	(0.0126)
ICT	0.0622	-0.1227***	0.0605	0.0236	-0.1173***	0.0937***
	(0.0471)	(0.0410)	(0.0499)	(0.0424)	(0.0388)	(0.0325)
R&D	-0.5483	-0.4263**	0.9746*	0.6109	-0.8828***	0.2719
	(0.4246)	(0.2070)	(0.5143)	(0.3592)	(0.3151)	(0.3612)
OS	0.1360	0.0582**	-0.1942*	0.0543	0.0335	-0.0878
	(0.0842)	(0.0270)	(0.1031)	(0.0487)	(0.0296)	(0.0606)
DO	0.0136	0.0126	-0.0262	0.0047	0.0209	-0.0256
	(0.0554)	(0.0218)	(0.0607)	(0.0428)	(0.0220)	(0.0479)
W_H				0.1363***	-0.0630***	-0.0733***
				(0.0233)	(0.0210)	(0.0148)
W_M				-0.0930**	0.1265***	-0.0335
				(0.0376)	(0.0311)	(0.0277)
W_L				-0.0477**	-0.0615***	0.1092***
				(0.0222)	(0.0154)	(0.0229)
Observations	364	364	364	364	364	364
R-squared	0.8404	0.8813	0.4215	0.9032	0.9028	0.6843

SUREG fixed effects model. Dependent variable: wage bill shares of high, medium, and low skilled labour. Independent variables: log output (Y), log capital intensity (KInt), share of ICT investment in total investment (ICT), share of R&D expenditures in total expenditures (R&D), offshoring (OS), domestic outsourcing (DO), and log wages by skill group (W_H, W_M, W_L). Year dummies are included but coefficients not shown. Standard errors are clustered at the industry level. *** (**; *) denote significance at the one (five; ten) per cent level.

high and low skilled labour. The second proxy for technological change, research and development expenditures (R&D), is also negative for medium skilled labour (p=5%) and positive for low skilled labour (p=10%). If we consider the two technology variables jointly, then the estimates suggest that technological change contributes to a polarisation of labour demand in disfavour of medium skilled labour.

The coefficient of offshoring is positive but statistically insignificant for high skilled labour, positive but smaller for medium skilled labour (p=5%), and negative for low skilled labour (p=10%). Though the level of statistical significance is relatively low, these results are in line with the hypothesis that offshoring is biased in favour of higher skilled labour. Since the coefficient size increases in the skill level one may, at first sight, conclude that the skill bias applies for all parts of the skill distribution. We evaluate this aspect further below.

In specification (2) of table 4 wage bill shares are additionally regressed on wages. As discussed in section 4.1 we thereby aim to identify the effects of offshoring on relative employment of single skill groups. In the following we highlight the main qualitative differences and similarities between the results from specifications (1) and (2). First, we observe that most of the wage regressors are highly significant. This is not surprising, given that the wage bill shares are by definition a function of wages. Second, we observe patterns of polarisation in labour demand as a consequence of technological change, similar to before. Third, the coefficient of offshoring is still negative for low skilled labour and positive for medium and high skilled labour. However, the coefficients are now much smaller and not statistically significant.

This is a remarkable fact which suggests that the skill bias induced by offshoring operates predominantly through changes in relative wages and less so through changes in relative employment. This is a novel finding which runs counter to the classical argument that, in Germany, wage rigidities imposed by labour unions prevent relative wages to adjust and thus cause unemployment among low skilled labour. Also, this finding suggests that previous studies may have underestimated the skill bias induced by offshoring. Many of the existing studies estimate either versions of specification (2) or employment share regressions, thus effectively only capturing the employment channel. In light of our results this seems to be too restrictive. Particularly in the Anglo-Saxon countries, where wages are allegedly more flexible than in Germany, such a narrow focus on employment effects seems hard to defend.[27]

In table 5 we report results from t-tests on differences in parameters across skill groups based on the estimations from specification (1). The t-tests support the view that ICT investment is associated with a polarisation of labour demand. The difference in the coefficients of high and medium skilled labour is positive (coefficient=0.18, p=1%), the difference in the coefficients of medium and low skilled labour is negative (coefficient=-0.18, p=5%), and the difference in the coefficient of high and low skilled labour is statistically insignificant. In terms of R&D expenditures we observe a statistically significant bias against medium skilled and in favour of low skilled labour. Jointly with the ICT coefficients this reinforces our interpretation that technological change is associated with polarisation in labour demand. In terms of offshoring we observe statistically significant differences between high and low skilled labour (coefficient=0.33, p=10%) and between medium and low skilled labour (coefficient=0.25, p=5%), but not between high and medium skilled labour (coefficient=0.07, insignificant). Hence, while offshoring is biased against low skilled labour we find no clear evidence of a bias against medium skilled labour, contrary to our first impression.

In table 6 we show that our previous findings are qualitatively robust to the

[27] See also section 5.3 for robustness checks where we estimate employment share regressions.

Table 5: T-tests of differences in coefficients across equations

	High - Low	High - Medium	Medium - Low
ICT	0.0017	0.1849***	-0.1832**
	(0.9841)	(0.0093)	(0.0163)
R&D	-1.5229*	-0.1220	-1.4009**
	(0.0896)	(0.7693)	(0.0292)
OS	0.3302*	0.0778	0.2524**
	(0.0689)	(0.2587)	(0.0383)
DO	-0.0398	0.0010	0.0388
	(0.7206)	(0.9852)	(0.5830)

T-tests of differences in coefficients across the three equations in table 4, specification (1). For instance, the upper left field shows that the ICT coefficient in the equation for high skilled labour is by 0.0017 larger than the same coefficient in the equation for low skilled labour. The corresponding p-value (in parenthesis) is 0.9841. Hence, we can reject the hypothesis that the two coefficients are different from each other at conventional levels of statistical significance.

use of instrumental variable (IV) estimations. We use two stage least squares estimations and instrument for offshoring in the first stage using as instruments the current and past offshoring intensities for Austria and France. To establish whether instruments are reliable we conduct tests for underidentification and weak identification.[28] Underidentification is in all specifications rejected at the 10% level based on the Kleinbergen-Paap LM test. Weak identification is rejected based on the Kleinbergen-Paap Wald test. To establish whether instruments are valid we test whether overidentified instruments are uncorrelated with the error term using a Hansen J test. We cannot reject the hypothesis of valid instruments at the 10% level.

Notably, the IV estimations confirm that offshoring is skill-biased. Offshoring decreases the wage bill shares of low skilled labour and increases the wage bill shares of high skilled labour. The coefficient size and the statistical significance are even larger than before. An increase in offshoring by 1 percentage point is associated with a 0.24% increase in the wage bill share of high skilled labour and a a 0.22% decrease in the wage bill share of low skilled labour. Hence, according to simple back-of-the-envelope calculations, offshoring accounts for 29% (or +1.4ppt) of the observed increase in the wage bill share of high skilled labour between 1995 and 2007 and for 135% (or -1.3ppt) of the observed decrease in the wage bill share of low skilled labour.[29] Yet, the coefficient of offshoring is small and statistically

[28]Based on these tests we chose the current value and the first lag of offshoring in Austria as instruments for specification (3) and the current and first lag of offshoring in Austria and France as instruments in specification (4). The results also hold qualitatively if we use lagged German offshoring and domestic outsourcing as instruments for current German offshoring and domestic outsourcing. We prefer our main instruments, however, since uncorrelatedness with the error term is more likely to be satisfied.

[29]The first number (+1.4) is obtained by multiplying the estimated coefficient (0.2367) by the observed average change in offshoring (+0.0598) and then dividing by the observed average change

Table 6: Instrumental variables estimations

	(3)			(4)		
	High	Medium	Low	High	Medium	Low
Y	-0.0229***	-0.0038	0.0266***	-0.0136**	-0.0016	0.0152**
	(0.0073)	(0.0028)	(0.0072)	(0.0056)	(0.0044)	(0.0061)
KInt	0.0014	-0.0096	0.0082	0.0001	-0.0006	0.0005
	(0.0161)	(0.0087)	(0.0153)	(0.0116)	(0.0087)	(0.0128)
ICT	0.0782*	-0.1140***	0.0358	0.0283	-0.1101***	0.0818***
	(0.0440)	(0.0387)	(0.0421)	(0.0381)	(0.0358)	(0.0266)
R&D	-0.4971	-0.5134**	1.0104*	0.7726**	-0.9429***	0.1703
	(0.5154)	(0.2345)	(0.5617)	(0.3875)	(0.3317)	(0.3537)
OS	0.2367**	-0.0212	-0.2155**	0.0581	-0.0061	-0.0520
	(0.1184)	(0.0568)	(0.1063)	(0.0704)	(0.0434)	(0.0629)
DO	0.0475	-0.0121	-0.0354	0.0061	0.0062	-0.0123
	(0.0553)	(0.0264)	(0.0564)	(0.0407)	(0.0246)	(0.0430)
W_H				0.1367***	-0.0647***	-0.0720***
				(0.0222)	(0.0200)	(0.0124)
W_M				-0.0951***	0.1285***	-0.0334
				(0.0346)	(0.0300)	(0.0247)
W_L				-0.0464**	-0.0612***	0.1076***
				(0.0188)	(0.0142)	(0.0203)
KP LM pval	0.0505	0.0505	0.0505	0.0531	0.0531	0.0531
KP Wald Fstat	10.71	10.71	10.71	21.26	21.26	21.26
Hansen J pval	0.708	0.387	0.702	0.266	0.294	0.975
Observations	336	336	336	336	336	336
R-squared	0.8325	0.8739	0.4213	0.9086	0.8974	0.7038

Instrumental variable fixed effects model. Instruments are the current and past offshoring intensities for Austria (specification 3) and for Austria and France (specification 4). Dependent variable: wage bill shares of high, medium, and low skilled labour. Independent variables: log output (Y), log capital intensity (KInt), share of ICT investment in total investment (ICT), share of R&D expenditures in total expenditures (R&D), offshoring (OS), domestic outsourcing (DO), and log wages by skill group (W_H, W_M, W_L). Year dummies are included but coefficients not shown. Standard errors are clustered at the industry level. *** (**; *) denote significance at the one (five; ten) per cent level.

insignificant for medium skilled labour. By contrast, ICT investment and R&D expenditures can jointly explain 20% (or -0.8ppt) of the observed decline in the wage bill share of medium skilled labour, thus adding to the evidence that technological change causes a polarisation of labour demand.

5.2 Effects by offshoring destination, input type, and sector

In table 7 we analyse whether the previously identified effects depend on the destinations of offshoring or the type of offshored inputs, using SUREG estimations.[30] In specification (5) we distinguish between offshoring to OECD countries, Cental and Eastern European countries (CEEC), China, and the "rest of the world" (RoW)

in the wage bill share of high skilled labour (+0.0487).

[30] We also estimated IV versions of these models. Using the first and second lag of offshoring and domestic outsourcing as instruments, results are similar to the reported SUREG estimates. Note however that our preferred instruments (offshoring in Austria and France) are not sufficiently correlated with offshoring in Germany in these specifications.

Table 7: Offshoring by destinations and types of inputs (SUREG fixed effects model)

	(5)			(6)		
	High	Medium	Low	High	Medium	Low
Y	-0.0218**	0.0031	0.0187**	-0.0234**	0.0034	0.0201**
	(0.0098)	(0.0039)	(0.0090)	(0.0093)	(0.0039)	(0.0089)
KInt	-0.0092	-0.0003	0.0095	-0.0232**	-0.0051	0.0282**
	(0.0131)	(0.0068)	(0.0139)	(0.0111)	(0.0050)	(0.0112)
ICT	0.0501	-0.1291***	0.0790*	0.0546	-0.1257***	0.0711
	(0.0408)	(0.0425)	(0.0444)	(0.0532)	(0.0387)	(0.0507)
R&D	0.4139	-0.0890	-0.3249	-0.0737	-0.1977	0.2714
	(0.4985)	(0.2253)	(0.5542)	(0.4213)	(0.1905)	(0.4716)
OS to OECD	0.1173	0.0150	-0.1323			
	(0.1122)	(0.0504)	(0.1217)			
. . . to CEEC	1.0490***	0.3919**	-1.4408***			
	(0.3111)	(0.1557)	(0.3557)			
. . . to China	0.2007	-0.0117	-0.1890			
	(0.2225)	(0.0899)	(0.2297)			
. . . to RoW	0.1305	0.0865***	-0.2170*			
	(0.1052)	(0.0262)	(0.1102)			
. . . of materials				0.2005*	0.0982**	-0.2987**
				(0.1144)	(0.0373)	(0.1321)
. . . of services				-0.2060	-0.1082	0.3142
				(0.2189)	(0.1144)	(0.2841)
DO	0.0090	0.0133	-0.0223	-0.0113	0.0033	0.0080
	(0.0525)	(0.0211)	(0.0513)	(0.0456)	(0.0205)	(0.0507)
Observations	364	364	364	364	364	364
R-squared	0.8567	0.8843	0.5602	0.8448	0.8834	0.4740

SUREG fixed effects model. Dependent variable: wage bill shares of high, medium, and low skilled labour. Independent variables: log output (Y), log capital intensity (KInt), share of ICT investment in total investment (ICT), share of R&D expenditures in total expenditures (R&D), domestic outsourcing (DO), and offshoring (OS) by destination or type of input. Year dummies are included but coefficients not shown. Standard errors are clustered at the industry level. *** (**; *) denote significance at the one (five; ten) per cent level.

consisting predominantly of low-wage countries. The coefficients for CEEC and ROW are highly statistically significant and show clear patterns of skill biases. For the OECD and, surprisingly, China coefficients are not statistically significant. The coefficients for CEEC are particularly large, which suggests that the economic integration of CEEC into the European Union since the 1990s has entailed major distributional effects in Germany. An increase in offshoring to CEEC by 1 percentage point is associated with a 1.04% increase in the wage bill share of high skilled labour, a 0.39% increase for medium skilled labour, and a 1.44% decrease for low skilled labour.

In specification (6) we distinguish between two different types of inputs. Offshoring of material inputs (material offshoring) shows a pattern of skill bias which is qualitatively similar to the estimate for the broad offshoring measure and quantitatively larger. Offshoring of service inputs (service offshoring), by contrast, is not statistically significant. We note, however, that the size of the coefficients is

Table 8: Manufacturing and service sector (SUREG fixed effects model)

		(7)	
VARIABLES	High	Medium	Low
Y	-0.0242***	0.0060	0.0181***
	(0.0068)	(0.0040)	(0.0063)
KInt	-0.0138	0.0009	0.0129
	(0.0103)	(0.0071)	(0.0125)
ICT	0.0374	0.1419	-0.1793
	(0.1339)	(0.0976)	(0.1249)
R&D	-0.4165	-0.2481	0.6645*
	(0.3035)	(0.1788)	(0.3522)
OS	0.1061**	0.0651*	-0.1712***
	(0.0470)	(0.0362)	(0.0560)
DO	0.2020**	0.0920**	-0.2940**
	(0.0851)	(0.0437)	(0.1122)
SER * ICT	0.0511	-0.2712***	0.2200*
	(0.1349)	(0.0818)	(0.1282)
SER * R&D	2.8596*	-1.3637	-1.4959
	(1.4021)	(0.8148)	(1.2526)
SER * OS	-0.4506***	-0.1196**	0.5702***
	(0.0895)	(0.0556)	(0.1036)
SER * DO	-0.0510	-0.0461	0.0970
	(0.0794)	(0.0505)	(0.0759)
T-tests for the service sector			
Null hypotheses:		p-values	
ICT + SER * ICT = 0	0.0694*	0.0078***	0.3200
R&D + R&D * ICT = 0	0.0849*	0.0584*	0.4940
OS + SER * OS = 0	0.0546*	0.6530	0.0589*
DO + SER * DO = 0	0.4000	0.5150	0.2610
Observations	364	364	364
R-squared	0.8697	0.8904	0.6276

SUREG fixed effects model. Dependent variable: wage bill shares of high, medium, and low skilled labour. Independent variables: log output (Y), log capital intensity (KInt), share of ICT investment in total investment (ICT), share of R&D expenditures in total expenditures (R&D), domestic outsourcing (DO), and offshoring (OS). Shift variables are interacted with service sector dummy (SER). Year dummies are included but coefficients not shown. Standard errors are clustered at the industry level. *** (**; *) denote significance at the one (five; ten) per cent level.

reversed. This finding is in line with the hypothesis that high skilled labour is not shielded from offshoring when it comes to service activities such as accounting or IT services.

We further explore the differences between materials and services in table 8. Here we allow for heterogeneous effects of offshoring and technological change in the manufacturing sector vis-à-vis the service sector by multiplying each shift variable with a service sector dummy. Note that, different from the previous estimations, this is not a distinction by type of offshored input but rather a distinction of offshoring effects by economic sectors.

Notably, we find that offshoring and ICT investment exert heterogeneous effects in the two sectors, where the effects for low skilled workers are always more benign in the service sector. First, we focus on offshoring. We observe a pattern consistent with skill bias in the manufacturing sector and the converse bias in the service sector. The total effect for the service sector (i.e. main effect + interaction effect) is positive for low skilled labour and negative for high and medium skilled labour. The t-tests at the bottom of the table show that the coefficients are statistically significant for high and low skiled labour (p=10%). Second, we focus on ICT investment. We observe an imprecisely estimated bias against low skilled labour in the manufacturing sector and a pattern broadly consistent with polarisation in the service sector. In the service sector, ICT investment is negatively linked with the wage bill share for medium skilled labour (p=1%) and positively for high skilled labour (p=5%).

To answer the question of what is driving these sectoral differences we should, first of all, recall the results from specification (6) in table 7 which revealed a clear skill bias in material offshoring and the converse (though insignificant) bias in service offshoring. This aspect complements our findings on sector differences, suggesting that differences in the type of offshored inputs or activities matter. As highlighted in Blinder (2006, 2009) many skilled service sector jobs are easily "offshorable" due to the nature of the tasks that characterise these jobs. Blinder argues that offshorability in the service sector depends crucially on the requirement of physical presence (e.g. janitorial services) or face-to-face contact (e.g. taxi driving) and not primarily on skills. Moreover, Blinder and other authors have highlighted the close link between innovations in ICT and offshoring. ICT innovations dramatically expand the scope of offshorable activities. At the same time, ICT innovations often allow for an automation of tasks that were previously performed by, mostly, medium skilled labour. Several studies have therefore argued that technological change related to ICT may contribute to a polarisation in labour demand (Spitz-Oener, 2006; Acemoglu and Autor, 2011; Autor and Dorn, 2013). Our findings are consistent with these arguments.

5.3 Robustness checks

First, we check the robustness of one of our main results from section 5.1, where we found that offshoring affects the wage bill shares of high, medium, and low skilled labour mainly through changes in relative wages and less so through changes in relative employment. Recall that this finding runs counter to the widespread perception that German wage structures were rigid and largely exogenous to changes in offshoring.

To reassess this issue we estimate "employment share equations" using the

Table 9: Employment share regressions (IV fixed effects model)

	(8)			(9)		
	High	Medium	Low	High	Medium	Low
Y	-0.0101*	-0.0160***	0.0262***	-0.0090*	-0.0129***	0.0219***
	(0.0053)	(0.0058)	(0.0059)	(0.0052)	(0.0049)	(0.0068)
KInt	-0.0039	-0.0003	0.0042	0.0013	-0.0085	0.0072
	(0.0111)	(0.0112)	(0.0141)	(0.0116)	(0.0077)	(0.0129)
ICT	-0.0048	-0.0776**	0.0824*	0.0082	-0.1137***	0.1055***
	(0.0379)	(0.0395)	(0.0439)	(0.0364)	(0.0315)	(0.0386)
R&D	1.1820***	-2.0259***	0.8440*	0.8133**	-1.1410***	0.3277
	(0.3161)	(0.5203)	(0.5106)	(0.3740)	(0.3548)	(0.4110)
OS	-0.0052	0.1449*	-0.1397	0.0419	-0.0081	-0.0338
	(0.0779)	(0.0857)	(0.0861)	(0.0676)	(0.0381)	(0.0611)
DO	-0.0152	0.0411	-0.0259	0.0052	-0.0044	-0.0008
	(0.0350)	(0.0365)	(0.0454)	(0.0390)	(0.0208)	(0.0395)
W_H				-0.0389**	0.0899***	-0.0510***
				(0.0193)	(0.0200)	(0.0149)
W_M				0.0417	-0.0682**	0.0264
				(0.0280)	(0.0308)	(0.0262)
W_L				-0.0073	-0.0200	0.0273
				(0.0161)	(0.0133)	(0.0204)
KP LM pval	0.0505	0.0505	0.0505	0.0531	0.0531	0.0531
KP Wald Fstat	10.71	10.71	10.71	21.26	21.26	21.26
Hansen J pval	0.218	0.405	0.958	0.284	0.109	0.942
Observations	336	336	336	336	336	336
R-squared	0.8322	0.7482	0.4498	0.8460	0.8217	0.5162

Instrumental variable fixed effects model. Instruments are the current and past offshoring intensities for Austria (specification 3) and for Austria and France (specification 4). Dependent variable: employment shares of high, medium, and low skilled labour, measured in terms of hours worked. Independent variables: log output (Y), log capital intensity (KInt), share of ICT investment in total investment (ICT), share of R&D expenditures in total expenditures (R&D), offshoring (OS), domestic outsourcing (DO), and log wages by skill group (W_H, W_M, W_L). Year dummies are included but coefficients not shown. Standard errors are clustered at the industry level. *** (**; *) denote significance at the one (five; ten) per cent level.

shares of high, medium, and low skilled labour in total hours worked as dependent variables. In the literature similar models have been estimated either with excluded wage regressors (Strauss-Kahn, 2004; Helg and Tajoli, 2005; Lorentowicz et al., 2008), included wage regressors (Anderton and Brenton, 1999; Egger and Egger, 2003; Hijzen et al., 2005), or with both types of specifications (Machin and van Reenen, 1998; Ekholm and Hakkala, 2006). We note that the model with *excluded* wage regressors is not fully suitable to differentiate between wage and employment effects, because if offshoring actually affects wages then this model suffers from omitted variable bias. Still, we estimate both types of specifications, to make our results comparable with other studies. The results of our IV fixed effects estimations are display in table 9.[31]

In specification (8) of table 9 we observe that offshoring has no statistically

[31] Note that the first stage regressions of the employment share model are identical to the first stage regressions of the wage bill share model, reported in table 6. Hence, the tests for underidentification and weak identification are also identical.

significant effects on the employment shares of high skilled and low skilled labour, contrary to the evidence from the wage bill share estimations (see table 6). Offshoring is positive and weakly statistically significant for medium skilled labour. Adding wage controls in specification (9) we observe that the sign of the offshoring coefficients is in line with skill bias, but all coefficients are small compared to the corresponding coefficients of the wage bill share regressions, and statistically insignificant. This supports our previous finding that offshoring affects the relative labour market outcomes of high, medium, and low skill labour predominantly through the wage channel and less so through the employment channel.

Second, economic theory implies certain restrictions on the wage parameters in order for the cost function to be well behaved (see Berndt, 1991, pp. 469ff). In particular, symmetry implies: $\gamma_{st} = \gamma_{ts}\ \forall s,t \in S = [H,M,L]$. Moreover, homogeneity of degree 1 in wages implies: $\sum_{s\in S}\beta_s = 1$ and $\sum_s \gamma_{st} = \sum_s \gamma_{ts} = \sum_s \gamma_{sY} = 0$. As a robustness check we test for several of these restrictions using the baseline estimations in specification (2) of table 4. It turns out that the adding up conditions $\sum_s \gamma_{st} = 0$ hold in all equations, whereas symmetry only holds in two of three equations. We must reject the null hypothesis $\gamma_{ML} = \gamma_{LM}$ at the 10% level.

Too rule out that this affects our results, we re-estimate this model with imposed parameter restrictions. As pointed out in section 4.2 we estimate the SUREG model using maximum likelihood to ensure that our results are invariant to the choice of the equation to be dropped. The constrained estimations, displayed in table 10, qualitatively confirm our main results. The only notable change is that the coefficient of *R&D* in the equation for high skilled labour turns from insignificant to significant at the 5% level. We also calculate the own-price elasticities of factor demand at the mean of wage bill shares, which are given for the translog cost function by $\varepsilon_{ss} = \frac{\gamma_{ss}}{WSH_s} + WSH_s - 1$ (Berndt, 1991, p. 475). The own-price elasticities for high and medium skilled labour are negative, as expected. The own-price elasticities for low skilled labour is positive, violating economic theory. Thus, we note that the estimations with included wage regressors have to be interpreted with some caution.

6 Conclusion

The paper analyses the effects of offshoring on labour market inequalities between skill groups. Different from previous studies we address the question whether offshoring affects the labour market outcomes through changes in relative wages or

Table 10: Constrained SUREG model

	(10)		
	High	Medium	Low
Y	-0.0217***	0.0029	0.0188***
	(0.0064)	(0.0039)	(0.0064)
KInt	-0.0044	0.005	-0.0006
	(0.0106)	(0.0071)	(0.0124)
ICT	0.0210	-0.1147***	0.0937***
	(0.0394)	(0.037)	(0.0312)
R&D	0.5716**	-0.9135***	0.3419
	(0.2837)	(0.2861)	(0.3146)
OS	0.0423	0.0408	-0.0831
	(0.0452)	(0.0272)	(0.0582)
DO	0.0007	0.0235	-0.0242
	(0.0418)	(0.0213)	(0.0458)
W_H	0.1264***	-0.0643***	-0.0621***
	(0.0179)	(0.0200)	(0.0125)
W_M	-0.0643***	0.1198***	-0.0555***
	(0.0200)	(0.0200)	(0.0143)
W_L	-0.0621***	-0.0555***	0.1176***
	(0.0125)	(0.0143)	(0.0181)
Constant	0.5565***	0.5820***	-0.1385
	(0.0891)	(0.0735)	(0.0861)
ε_{ss}	-0.2752	-0.1931	0.074
Obs	364	364	364

Constrained SUREG fixed effects model. Imposes symmetry and homogeneity of degree 1 in wages. Invariance to dropping of one equation is achieved through maximum likelihood estimation. Wage Dependent variable: wage bill shares of high, medium, and low skilled labour, measured in terms of hours worked. Independent variables: log output (Y), log capital intensity (KInt), share of ICT investment in total investment (ICT), share of R&D expenditures in total expenditures (R&D), offshoring (OS), domestic outsourcing (DO), and log wages by skill group (W_H, W_M, W_L). Year dummies are included but coefficients not shown. Standard errors are clustered at the industry level. *** (**; *) denote significance at the one (five; ten) per cent level. ε_{ss} is the own-wage elasticity of the demand for skill group s.

through changes in relative employment. Also, we analyse whether offshoring can explain the diverging trends in the manufacturing and the service sector. Our analysis is based on data for 28 industries and three skill groups in Germany between 1995 and 2007. We derive our empirical model from an industry short-run cost function with three types of labour inputs (high, medium, and low skilled workers) which is augmented by offshoring, domestic outsourcing, and technological change. We estimate the resulting system of three wage bill share equations using seemingly unrelated regression and instrumental variable regressions.

Our main results are the following: We find that offshoring is on average over all industries biased in favour of high skilled labour and in disfavour of low skilled labour. Offshoring can explain about 30% of the observed increase in the share of high skilled workers in the total wage bill and 135% of the observed decline in the share of low skilled workers, based on our instrumental variable estimates. These effects are mostly driven by offshoring to Central and Eastern European countries and by material offshoring. Contrary to widely held believes we find that offshoring affects labour market outcomes mainly through changes in relative wages rather than changes in relative employment. This result runs counter to the argument that German labour market institutions (such as collective bargaining and unemployment benefits) prevent relative wages to adjust and thus cause unemployment among low skilled labour. Also, this finding suggests that previous studies may have underestimated the skill bias induced by offshoring.

While we find that offshoring is skill-biased in the manufacturing sector, we find the opposite direction of bias in the service sector. This is in line with the hypothesis that low skilled service workers are shielded from offshoring by the nature of tasks they perform (Blinder, 2006, 2009), but it is not in line with the hypothesis that offshoring causes polarisation in labour demand. However, unlike offshoring, we find that technological change is indeed associated with polarisation in labour demand.

In light of our findings several questions for future research emerge: How will offshoring in the long run affect the demand for skills in developed countries, given the growing relative importance of the service sector and the increasing offshorability of medium- and high-skill intensive services? How will offshoring and technological change shape the the future nature of work, and how is this nature of work related to skills? Also, it should be analysed whether labour markets of other countries adjust to offshoring through changes in relative wages or employment, and relate this to prevailing labour market institutions. From the perspective of policy makers these issues are of high relevance, because they may help them redesign national education systems and labour market institutions in such a way that citizens are prepared for the future nature of work.

7 Bibliography

Abraham, Katharine G., and Susan Houseman (1995) ‘Earnings inequality in germany.’ In *Differences and Changes in Wage Structures,* ed. Richard B. Freeman and Lawrence F. Katz (Chicago and London: The University of Chicago Press) pp. 371–404

Acemoglu, Daron (2003) ‘Cross-country inequality trends.’ *The Economic Journal* 113(485), pp. F121–F149

Acemoglu, Daron, and David H. Autor (2011) ‘Skills, tasks and technologies: Implications for employment and earnings.’ In *Handbook of Labor Economics,* ed. O. Ashenfelter and D. Card, vol. 4 (Elsevier) chapter 12, pp. 1043–1171

Amiti, Mary, and Shang-Jin Wei (2009) ‘Service offshoring and productivity: Evidence from the us.’ *World Economy* 32(2), 203–220

Anderton, Bob, and Paul Brenton (1999) ‘Outsourcing and low-skilled workers in the uk.’ *Bulletin of Economic Research* 51(4), 267–85

Arndt, Sven W. (1997) ‘Globalization and the open economy.’ *The North American Journal of Economics and Finance* 8(1), 71–79

Autor, David H., and David Dorn (2013) ‘The growth of low-skill service jobs and the polarization of the us labor market.’ *American Economic Review* 103(5), 1553–97

Autor, David H., Frank Levy, and Richard J. Murnane (2003) ‘The skill content of recent technological change: An empirical exploration.’ *The Quarterly Journal of Economics* 118(4), 1279–1333

Baumgarten, Daniel, Ingo Geishecker, and Holger Görg (2013) ‘Offshoring, tasks, and the skill-wage pattern.’ *European Economic Review* 61(C), 132–152

Becker, Sascha O., Karolina Ekholm, and Marc-Andreas Muendler (2013) ‘Offshoring and the onshore composition of tasks and skills.’ *Journal of International Economics* 90(1), 91–106

Berman, Eli, John Bound, and Zvi Griliches (1993) ‘Changes in the demand for skilled labor within u.s. manufacturing industries: Evidence from the annual survey of manufacturing.’ NBER Working Papers 4255, National Bureau of Economic Research

Berman, Eli, John Bound, and Zvi Griliches (1994) ‘Changes in the demand for skilled labor within u.s. manufacturing: Evidence from the annual survey of manufacturers.’ *The Quarterly Journal of Economics* 109(2), 367–397

Berndt, Ernst R. (1991) *The Practice of Econometrics: Classic And Contemporary* (Reading, Mass.: Addison-Wesley)

Blinder, Alan S. (2006) ‘Offshoring: The next industrial revolution?’ *Foreign Affairs* 85(2), 113–128

Blinder, Alan S. (2009) ‘How many us jobs might be offshorable?’ *World Economics* 10(2), 41–78

Card, David, Jörg Heining, and Patrick Kline (2013) ‘Workplace heterogeneity and the rise of west german wage inequality.’ *The Quarterly Journal of Economics* 128(3), 967–1015

Castellani, Davide, Luca de Benedictis, and Daniel Horgos (2013) ‘Can we really trust offshoring indices?’ *Structural Change and Economic Dynamics* 25(C), 159–172

Christensen, Björn, and Axel Schimmelpfennig (1998) ‘Arbeitslosigkeit, qualifikation und lohnstruktur in westdeutschland.’ *Die Weltwirtschaft: Vierteljahresschrift des Instituts für Weltwirtschaft an der Universität Kiel* 2, 177–186

Crinò, Rosario (2009) ‘Offshoring, multinationals and labour market: A review of the empirical literature.’ *Journal of Economic Surveys* 23(2), 197–249

_ (2010) ‘Service offshoring and white-collar employment.’ *Review of Economic Studies* 77(2), 595–632

_ (2012) ‘Service offshoring and the skill composition of labour demand.’ *Oxford Bulletin of Economics and Statistics* 74(1), 20–57

Deardorff, Alan V. (2001) ‘Fragmentation in simple trade models.’ *The North American Journal of Economics and Finance* 12(2), 121–137

Dustmann, Christian, Johannes Ludsteck, and Uta Schönberg (2009) ‘Revisiting the german wage structure.’ *The Quarterly Journal of Economics* 124(2), 843–881

Egger, Hartmut, and Peter Egger (2003) 'Outsourcing and skill-specific employment in a small economy: Austria after the fall of the iron curtain.' *Oxford Economic Papers* 55(4), 625–643

Egger, Hartmut, and Peter Egger (2005) 'Labor market effects uf outsourcing under industrial interdependence.' *International Review of Economics & Finance* 14(3), 349–363

Egger, Hartmut, and Peter Egger (2006) 'International outsourcing and the productivity of low-skilled labor in the eu.' *Economic Inquiry* 44(1), 98–108

Ekholm, Karolina, and Katariina Hakkala (2006) 'The effect of offshoring on labour demand: Evidence from sweden.' CEPR Discussion Papers 5648, CEPR

Falk, Martin, and Bertrand M. Koebel (2002) 'Outsourcing, imports and labour demand.' *Scandinavian Journal of Economics* 104(4), 567–86

Feenstra, Robert C., and Gordon H. Hanson (1996a) 'Foreign investment, outsourcing and relative wages.' In *The Political Economy of Trade Policy: Papers in Honor of Jagdish Bhagwati,* ed. Robert C. Feenstra, Gene M. Grossman, and Douglas A. Irwin, vol. 1 of *MIT Press Books* (The MIT Press)

_ (1996b) 'Globalization, outsourcing, and wage inequality.' *American Economic Review* 86(2), 240–45

Feenstra, Robert C., and Gordon H. Hanson (1999) 'The impact of outsourcing and high-technology capital on wages: Estimates for the united states, 1979-1990.' *The Quarterly Journal of Economics* 114(3), 907–940

Feenstra, Robert C., and J. Bradford Jensen (2012) 'Evaluating estimates of materials offshoring from us manufacturing.' *Economics Letters* 117(1), 170–173

Fitzenberger, Bernd (1999) *Wages and Employment Across Skill Groups. An Analysis for West Germany* , ZEW Economic Studies, 6 (Physica)

Freeman, Richard B., and Lawrence F. Katz (1995) 'Introduction and summary.' In 'Differences and Changes in Wage Structures' (The University of Chicago Press, Chicago: National Bureau of Economic Research) pp. 1–22

Freeman, Richard B., and Ronald Schettkat (2001) 'Skill compression, wage differentials, and employment: Germany vs the us.' *Oxford Economic Papers* 53(3), 582–603

Geishecker, Ingo (2006) ‘Does outsourcing to central and eastern europe really threaten manual workers’ jobs in germany?’ *The World Economy* 29(5), 559–583

Geishecker, Ingo, and Holger Görg (2008) ‘Winners and losers: A micro-level analysis of international outsourcing and wages.’ *Canadian Journal of Economics* 41(1), 243–270

Geishecker, Ingo, and Holger Görg (2013) ‘Services offshoring and wages: Evidence from micro data.’ *Oxford Economic Papers* 65(1), 124–146

Goos, Maarten, Alan Manning, and Anna Salomons (2009) ‘Job polarization in europe.’ *The American Economic Review* 99(2), 58–63

Gottschalk, Peter, and Timothy M. Smeeding (1997) ‘Cross-national comparisons of earnings and income inequality.’ *Journal of Economic Literature* 35(2), 633–687

Gould, William, Jeffrey Pitblado, and William Sribney (2003) *Maximum Likelihood Estimation with STATA* (College Station, Tex.: Stata Press)

Greene, Wiliam H. (2002) *Econometric Analysis,* 5 ed. (London: Prentice Hall)

Görg, Holger, and Aoife Hanley (2005) ‘International outsourcing and productivity: Evidence from the irish electronics industry.’ *The North American Journal of Economics and Finance* 16(2), 255–269

Görg, Holger, Aoife Hanley, and Eric Strobl (2008) ‘Productivity effects of international outsourcing: Evidence from plant-level data.’ *Canadian Journal of Economics* 41(2), 670–688

Grossman, Gene M., and Esteban Rossi-Hansberg (2008) ‘Trading tasks: A simple theory of offshoring.’ *American Economic Review* 98(5), 1978–97

Helg, Rodolfo, and Lucia Tajoli (2005) ‘Patterns of international fragmentation of production and the relative demand for labor.’ *The North American Journal of Economics and Finance* 16(2), 233–254

Hijzen, Alexander, Holger Görg, and Robert C. Hine (2005) ‘International outsourcing and the skill structure of labour demand in the united kingdom.’ *Economic Journal* 115(506), 860–878

Jones, Ronald W., and Henryk Kierzkowski (2001) 'A framework for fragmentation.' In *Fragmentation: New Production Patterns in the World Economy,* ed. Sven W. Arndt and Henryk Kierzkowski (Oxford: Oxford University Press)

Katz, Lawrence F., and David H. Autor (1999) 'Changes in the wage structure and earnings inequality.' In *Handbook of Labor Economics,* ed. O. Ashenfelter and D. Card, vol. 3 of *Handbook of Labor Economics* (Elsevier) chapter 26, pp. 1463–1555

Kohler, Wilhelm (2001) 'A specific-factors view on outsourcing.' *The North American Journal of Economics and Finance* 12(1), 31–53

Kohler, Wilhelm (2004) 'International outsourcing and factor prices with multistage production.' *Economic Journal* 114(494), C166–C185

Krugman, Paul (1994) 'Past and prospective causes of high unemployment.' *Economic review (Federal Reserve Bank of Kansas City)* pp. 49–98

Leamer, Edward E., and Michael Storper (2001) 'The economic geography of the internet age.' *Journal of International Business Studies* 32(4), 641–665

Lorentowicz, Andzelika, Dalia Marin, and Alexander Raubold (2008) 'Is human capital losing from outsourcing?: Evidence for austria and poland.' In *Foreign Direct Investment and The Multinational Enterprise,* ed. Steven Brakman and Harry Garretsen (Cambridge, Mass.: MIT Press)

Machin, Stephen, and John van Reenen (1998) 'Technology and changes in skill structure: Evidence from seven oecd countries.' *The Quarterly Journal of Economics* 113(4), 1215–1244

Minondo, Asier, and Gloria Rubert (2006) 'The effect of outsourcing on the demand for skills in the spanish manufacturing industry.' *Applied Economics Letters* 13(9), 599–604

Morrison Paul, Catherine J., and Donald S. Siegel (2001) 'The impacts of technology, trade and outsourcing on employment and labor composition.' *Scandinavian Journal of Economics* 103(2), 241–64

Nickell, Stephen, and Brian Bell (1996) 'Changes in the distribution of wages and unemployment in oecd countries.' *American Economic Review* 86(2), 302–08

OECD (2011) *Divided We Stand: Why Inequality Keeps Rising* (OECD Publishing)

Prasad, Eswar S. (2004) 'The unbearable stability of the german wage structure: Evidence and interpretation.' *IMF Staff Papers* 51(2), 354–385

Puzzello, Laura (2012) 'A proportionality assumption and measurement biases in the factor content of trade.' *Journal of International Economics* 87(1), 105–111

Schöller, Deborah (2007) 'Service offshoring and the demand for less-skilled labor: Evidence from germany.' Hohenheimer Diskussionsbeiträge 287, University of Hohenheim

Schwörer, Tillmann (2013) 'Offshoring, domestic outsourcing and productivity: Evidence for a number of european countries.' *Review of World Economics* 149(1), 131–149

Spitz-Oener, Alexandra (2006) 'Technical change, job tasks, and rising educational demands: Looking outside the wage structure.' *Journal of Labor Economics* 24(2), 235–270

Strauss-Kahn, Vanessa (2004) 'The role of globalization in the within-industry shift away from unskilled workers in france.' In 'Challenges to Globalization: Analyzing the Economics' (National Bureau of Economic Research) pp. 209–234

Timmer, Marcel et al. (2012) 'The world input-output database (wiod): Contents, sources and methods.' Working Paper 10, WIOD

Venables, Anthony J. (1999) 'Fragmentation and multinational production.' *European Economic Review* 43(4-6), 935–945

Winkler, Deborah (2010) 'Services offshoring and its impact on productivity and employment: Evidence from germany, 1995–2006.' *The World Economy* 33(12), 1672–1701

Winkler, Deborah, and William Milberg (2009) 'Errors from the "proportionality assumption" in the measurement of offshoring: Application to german labor demand.' Working Paper 12, Schwartz Center for Economic Policy Analysis and New School for Social Research