

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Koerner, Konstantin

# Article — Published Version The wage effects of offshoring to the East and West: evidence from the German labor market

**Review of World Economics** 

**Provided in Cooperation with:** Springer Nature

*Suggested Citation:* Koerner, Konstantin (2022) : The wage effects of offshoring to the East and West: evidence from the German labor market, Review of World Economics, ISSN 1610-2886, Springer, Berlin, Heidelberg, Vol. 159, Iss. 2, pp. 399-435, https://doi.org/10.1007/s10290-022-00471-4

This Version is available at: https://hdl.handle.net/10419/308652

# Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.



WWW.ECONSTOR.EU

https://creativecommons.org/licenses/by/4.0/

#### Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



**ORIGINAL PAPER** 



# The wage effects of offshoring to the East and West: evidence from the German labor market

Konstantin Koerner<sup>1,2,3</sup>

Accepted: 13 May 2022 / Published online: 28 June 2022 © The Author(s) 2022

# Abstract

This paper analyzes the labor market effects of offshoring in a high-wage home country and how these effects crucially depend on (1) Job complexity and (2) The characteristics of the destination country. It thereby links several sources: rich administrative data on individuals and plants in the German manufacturing industries, information on a job's task bundle, and the evolution of imported inputs from low- or high-wage destinations, which are represented by Eastern and Western Europe, respectively. Offshoring to these origins has opposing effects on German wages with respect to the relative task complexity of jobs: While offshoring to the West puts pressure on the wages of complex jobs and increases the wages of simple jobs, offshoring to the East entails the opposite effect. The overall effect adds up to a 4.2 percent increase in wages for jobs with high complexity, while low-complexity jobs see a 3.9 percent decrease in wages.

Keywords Offshoring  $\cdot$  Tasks  $\cdot$  Production chains  $\cdot$  Offshorabiliy  $\cdot$  Wages  $\cdot$  Globalization

Mathematics Subject Classification F15 · F16 · J31

# **1** Introduction

# 1.1 Motivation and literature review

The most recent wave of globalization has broadly been driven by fostering international value chains and increasing trade in intermediate goods (Johnson & Noguera,

Konstantin Koerner konstantin.koerner@iab.de

<sup>&</sup>lt;sup>1</sup> Institute for Employment Research (IAB), Regensburger Str. 100, 90478 Nuremberg, Germany

<sup>&</sup>lt;sup>2</sup> Humboldt University of Berlin, Berlin, Germany

<sup>&</sup>lt;sup>3</sup> University of Regensburg, Regensburg, Germany

2017). Lower transport costs and new information technology have enabled industries to divide the manufacturing process into multiple parts, each of which fabricates a tradable output. Consequently, some production steps are offshored to benefit from international price differences. Specifically, relatively labor-intensive parts are moved to low-wage countries, whereas human-capital-intensive inputs are manufactured in high-wage countries (e.g., Carluccio et al., 2019). The resulting international value chain exploits comparative advantages through greater specialization in particular sets of tasks in source and destination countries. For the domestic labor market, this development emphasizes two counteracting forces. On the one hand, importing inputs substitutes for tasks formerly performed by domestic workers and thus places pressure on associated wages. On the other hand, it also reduces an industry's costs and boosts its productivity. Therefore, the industry's output expands, which, in turn, increases the demand for the remaining tasks in more specialized production and raises associated wages (Grossman & Rossi-Hansberg, 2008, 2012). In essence, any analysis of labor effects needs to consider the tasks substituted by imported inputs and the tasks that are allocated to complementary production.

Assuming that high-wage countries are skill abundant and specialize in particular human-capital-intensive goods, offshoring to these countries has different effects in terms of job substitution than offshoring to low-wage countries. Motivated by a steep increase in historically small trade flows (Fig. 1, or Krugman 2000), these effects have been the subject of fruitful discussion in recent decades. The literature has largely reached consensus that when not considering the characteristics of offshore production, offshoring lowers the relative demand for onshore workers without a college degree or for jobs with routine task profiles (e.g., Feenstra & Hanson, 1999; Becker et al., 2013; Baumgarten et al., 2013; Ebenstein et al., 2014; Hummels et al., 2014; Dauth et al., 2021).<sup>1</sup> Disagreement persists about the effects of offshored labor that is human-capital intensive, which is particularly surprising since the bulk of offshoring is between high-income countries and this type of trade has increased dramatically (Fig. 1). While Hummels et al. (2014, p. 1618 ff.) find a negative impact of offshoring to high-income countries on the Danish wages of low-skilled workers or routine jobs, Ebenstein et al. (2014, p. 588) reveal a positive wage impact on routine jobs in the US. Additionally, Mion & Zhu (2013) provide evidence from Belgian firms showing that imports from OECD countries negatively impact these firms' share of highly educated workers.

These studies show that it is essential to distinguish the type of labor in onshore and offshore (the type/origin of imported inputs) production when estimating the heterogeneous impact of offshoring on wages. In earlier studies, onshore labor has been distinguished by a *worker's* education, whereas more contemporary works, such as Autor & Handel (2013), have shown that a *job's* task profile is more relevant when estimating wage compensation. Moreover, the task approach is used

<sup>&</sup>lt;sup>1</sup> Related literature that does not distinguish either the type of affected labor or the type of imported inputs includes Moser et al. (2015) and Eppinger (2019), who focuses on the service sector. Beyond these examples, I refer to Hummels et al. (2018) for a comprehensive overview of the large body of literature on offshoring and labor markets.



**Fig. 1** Offshoring Intensity by Destination Region in German Manufacturing. *Source:* I-O Tables of the Federal Statistical Office of Germany (Fachserie 18, Reihe 2, Years: 1996–2007) and WIOT (2013), (Timmer et al., 2015). *Notes:* Offshoring intensity in German manufacturing is defined as the ratio of imported, intra-industry inputs relative to output. The left panel depicts region-specific offshoring from 1996 to 2007. The right panel displays the same shares less their 1996 values. From 1996 to 2002, off-shoring to Central and Eastern Europe and offshoring to Western Europe increased by approximately 0.8 percentage points. As sudden access to CEECs also poses a supply shock from the perspective of (other) Western European countries, the expansion of offshoring to Western Europe constitutes a remarkable increase

to distinguish labor by the costs of moving the job offshore, a characteristic that Blinder (2009) has named offshorability. In a more recent contribution, Blinder & Krueger (2013) find that well-paid workers and college graduates tend to hold jobs with higher offshorability and that they perform rather nonroutine tasks (e.g., mathematicians or programmers who can directly transfer their output via the Internet). While offshorable jobs are indeed prone to substitution with offshore labor (Goos et al., 2014), this vulnerability seems to be at odds with the fact that they are also the main gainers in terms of wages (e.g., Baumgarten et al., 2013). It is therefore doubtful whether the costs of moving a job offshore are the proper proxy for the manufacturing industry. In this sector, virtually every job is offshorable, as its tasks create a tangible good that can be sent to other regions (Blinder, 2006, p. 120). Then, the determining factor may again be the countries' comparative advantage in the production of goods that intensively require a specific set of tasks or type of labor. Regarding the wage effect of offshoring, these task inputs will then determine the substitutability of jobs.

#### 1.2 Contribution and research question

The present paper makes important contributions to the existing literature in several regards. First, it adds to Baumgarten et al. (2013) and distinguishes offshoring with respect to the income level of its destination to approximate the human-capital intensity in imported inputs. New stylized facts show that these imports have crucially distinct effects on factor intensity in production. Complex-task intensive industries offshore to high-income countries and become less complex-task intensive over time, while the opposite is true for offshoring to low-income countries. Second, this paper combines existing complexity indices by Becker et al. (2013) and Brändle & Koch (2017), so that a single measure is able to distinguish groups of heterogeneous labor that respond differently to the substituting and complementary forces of typical inputs from high- or low-wage countries. Third, this paper sheds light on the underexplored topic on wage effects of offshoring to other high-income countries. Using an instrumental variable (IV) approach, this paper finds that offshoring to high-income countries has negative wage effects for complex jobs, while it positively affects wages for simple jobs.

The detailed analysis is feasible, because this study merges rich administrative data on workers in the West German manufacturing sector during the 1995-2007 period with plant-level information, micro-level data on tasks from the German Qualification and Career Survey (BIBB-IAB work survey), and offshoring data from federal input-output tables. To quantify the wage effects for very nuanced types of labor, I use an index of job complexity, which builds on data from the BIBB-IAB work survey and combines a wide variety of job information about the versatility of tasks, performance requirements (such as responsibility), and the required level of various skills and abilities (similar to Ottaviano et al., 2013). Across manufacturing jobs, the index is not intended to approximate the costs of moving a specific task set offshore; rather, it approximates the relative human-capital intensity (e.g., skill, knowledge, and abilities) imparted in production at a fine occupational level. The measure for offshoring intensity uses data from the German Federal Statistical Office, which-in contrast to UN Comtrade data or the World Input-Output Tables—directly record the industries' imports of inputs or purchases from a domestic supplier. Combining this source with the WIOT distinguishes offshoring destinations with respect to their income levels and approximates the complexity-intensity of imported inputs (see Table 1). Thereby, the paper focuses on Germany's most prominent destinations for vertical integration and groups them into economically relatively homogeneous units: the (human-)capital intensive European Union in the late 1990s (EU15) and the labor-intensive Central and Eastern European countries (CEECs).<sup>2</sup>

How does offshoring to these country groups impacts changes in the price of occupational task bundles? This question is answered by estimating Mincer-type wage equations, at which wages are determined at the industry or occupation level. Specifically, the large employer-employee dataset makes it possible to include worker-plant, occupation, and plant-year fixed effects to extract offshoring's wage

<sup>&</sup>lt;sup>2</sup> The CEECs include the Czech Republic, Hungary, Poland, and Slovakia.

le 1eur 2000		
CEECs	EU15	Germany
38.87	155.56	145.23
5.20	27.45	32.68
0.6202	0.6605	0.7723
0.1369	0.2322	0.2904
	CEECs 38.87 5.20 0.6202 0.1369	CEECs         EU15           38.87         155.56           5.20         27.45           0.6202         0.6605           0.1369         0.2322

Table I Characteristics of Country Oroups in the Teat 200	Table 1	Characteristics	of Country	Groups in the	Year 2000
---	---------	-----------------	------------	---------------	-----------

Table 1 reports country group characteristics in 2000. The data is derived from the Socio Economic Accounts in the World Input-Output Database. It is converted into US-Dollars using exchange rates from the same source

impact within worker-plant matches while capturing endogenous plant-specific shocks (e.g., the exporter wage premium and new technology) of heterogeneous firms (e.g., Melitz, 2003) and asynchronous offshoring decisions within industries.

Despite the multidimensional fixed effects, wages and offshoring remain simultaneously determined, for example, because offshoring affects wages and wages affect the vulnerability to offshoring (e.g., offshoring activities could be more likely in relatively high-wage industries or occupations). This will bias the estimated coefficient of the causal wage impact of offshoring on wages. The analysis remedies these concerns by applying an IV regression, which extracts the exogenous variation in the offshoring variables. The choice of instruments builds on Autor et al. (2013), Baumgarten et al. (2013) and Hummels et al. (2014). It includes time-varying and region-specific instruments to suit the analysis with multiple trade partners. Accordingly, it utilizes the intermediate goods export supply of Germany's main offshoring destinations to other high-income countries. In the presence of the numerous fixed effects, these instruments depict an exogenous source of variation that is correlated with offshoring but independent of the wage-setting process in Germany.

The results confirm that offshoring has heterogeneous wage effects for manufacturing jobs that differ in complexity. Simple jobs benefit in terms of higher wage increases if domestic production expands the use of inputs from high-wage countries (EU15), while the relative wages of complex jobs suffer. Conversely, imported inputs from low-wage countries raise the wages of complex jobs but lower the wages of simple jobs. The overall effect adds up to a 4.2 percent increase in wages for a job with high complexity, while a low-complexity job sees a 3.9 percent decrease in wages.

#### 1.3 Germany's economic integration in Europe and its labor market

Germany is a very suitable case to explore the wage effects of region-specific offshoring, particularly in the late 1990s and 2000s. First, the country is very representative because it is Europe's largest economy. Second, it ranks among the countries with the highest trade volumes worldwide and experienced a steep rise in offshoring intensity in the late 1990s and 2000s (less though in the 2010s, see Figure C1 in the appendix).<sup>3</sup> Third, the fall of the Iron Curtain placed the country in a central position between an established trade bloc of high-wage, human-capital intensive countries in the west, the EU15, and low-wage, labor intensive countries in the east, that is, the CEECs (see, e.g., groupwise differences in the share of high-skilled workers in labor share in Table 1). Suddenly, Germany's geographic position became excellent to exploit international price differences within a short distance. This feature together with other political developments, that I describe in the following, vastly reduced the costs of offshoring and paved the way for the expansion of international value chains.

Eastward, the formerly separated CEECs featured relatively similar industrial and educational structures at substantially lower labor costs.<sup>45</sup> This phenomenon placed the German economy in a more competitive environment that was bolstered by several reductions in trade costs: In the early 1990s, the CEECs signed association agreements with the EU, which vastly cut tariffs. Trade flows, however, did not substantially increase until EU accession talks began in 1997. These negotiations endorsed the market system and institutions of the newly established democracies and, hence, gradually stabilized the investment climate. Moreover, it gave rise to the installation of foreign affiliates, even before these countries entered the EU in 2004. With these firms bringing in new production technology from their parent companies (Dustmann et al., 2014), the internal productivity and international competitiveness of suppliers in the CEECs rose steeply, resulting in vast expansions of imports from those regions to Germany.

Simultaneously, the EU politically reinforced the value chains among the EU15 countries. Beyond the already existing advantages of a customs union, the EU suppressed internal nontariff barriers by harmonizing regulations, laws, standards, and economic practices. European infrastructure projects and the establishment of the Schengen Area in 1995 lowered the costs of transportation, e.g., through new crossborder roads or time savings due to the abandonment of border controls. Furthermore, in 1999, the introduction of a common currency, the euro, abolished exchange rate fluctuations. Together, these measures vastly reduced the costs of offshoring.

How these events come along with offshoring from Germany to these destinations is depicted in Fig. 1. It clearly shows that offshoring to the EU15 exhibits substantially higher offshoring intensities than to any other country group. From 1996 to 2007, the share of inputs from the EU15 relative to industry output in Germany grew by 0.91 percentage points, or 25 percent of its initial value (Table C1 in the appendix). The right panel emphasizes the increasing relevance of CEECs as

<sup>&</sup>lt;sup>3</sup> Beginning in the late 1990s, Germany transformed its economy within ten years from high unemployment rates, relatively low GDP growth rates, record budget deficits, and mass protest rallies into a highly competitive "role model" economy exhibiting better economic performance than most European countries, even in times of global economic crisis. Some authors refer to this development as the rise "From [the] Sick Man of Europe to Economic Superstar" (e.g., Dustmann et al., 2014; Economist, 2004). German exports evolved very well, leading to substantial trade surpluses. In particular, the share of German manufacturing goods in world exports increased to more than ten percent in 2012.

<sup>&</sup>lt;sup>4</sup> Before the Iron Curtain separated the CEECs and Germany, these countries shared a long history of trade (Dustmann et al., 2014, p. 182).

<sup>&</sup>lt;sup>5</sup> Poland and Hungary, for instance, practice the same focus on vocational training as Germany. Furthermore, a considerable number of Central and Eastern European workers are German speaking (Winkler, 2010).



offshoring destinations. While this country group exhibits low initial values of economic integration with Germany, from 1996 to 2007, offshoring to these countries increased by 1.1 percentage points, or 318 percent.<sup>6</sup>

While the German goods market is characterized by large and growing trade volumes, the increase in output demand did not immediately translate into growth of the labor market. In fact, the labor market has instead been characterized by rather high rates of unemployment and wage polarization.<sup>7</sup> It seems that the evolution of trade comes along with a change in the demand for (or the marginal product of) certain types of labor.

Figure 2 illustrates the divergence in average real wages for the terciles of the complexity distribution. It reveals that income growth is unequally distributed and varies by job complexity. While the wages of complex jobs rise by 13 percent, the compensation for intermediate jobs rises by approximately 8 percent, and wages of simple jobs increase by less than 5 percent.<sup>8</sup>

The remainder of this paper is structured as follows. Section 2 presents the various datasets employed in the analysis. Then, Sect. 3 explains the estimating equation and the identification strategy for the empirical analysis. Section 4 compiles the results, which are checked for robustness in Sect. 5. Finally, Sect. 6 concludes the paper.

#### 2 Data description

This section introduces the various datasets employed in the analysis and provides summary information on data construction and measurement. For details on the sampling procedure and data processing, I refer to the appendix.

<sup>&</sup>lt;sup>6</sup> There is substantially more intra-industry trade between Germany and CEECs than with other emerging economies such as China (Fig. 1, or Dauth et al., 2014, p. 1650 f.).

<sup>&</sup>lt;sup>7</sup> The gap between high and low incomes remained fairly stable in the 1970s and 1980s. Starting in the 1990s, inequality rose, which is especially attributable to developments at the lower end of the wage distribution (Dustmann et al., 2009; Gernandt & Pfeiffer, 2007). Dustmann et al. (2014) argues that the credible threat of relocating German jobs to CEECs led to higher rates of decentralized wage setting and the introduction of "opening clauses" in industry-wide agreements (see also Table 3). These changes led to flexibility in industrial relations and to wage moderation.

<sup>&</sup>lt;sup>8</sup> Note, however, that the overall divergence tends to be understated because censored top-income earners are not included. For more detailed information on labor market developments, see Dustmann et al. (2009) or Dustmann et al. (2014).

#### 2.1 Linked employer-employee data

I extract matched information on workers and plants from a longitudinal version of the Linked Employer-Employee (LIAB MM 9308) dataset of the Institute for Employment Research (IAB).<sup>9</sup> The LIAB has important features for the analysis at hand. First, it is designed to provide a long time dimension with many entries per employer, which is well suited to the objective of capturing unobserved heterogeneity in plants or individuals through multidimensional fixed effects.

Second, the LIAB samples the most comprehensive dataset of workers in Germany, comprising the universe of employees subject to social security (approximately 80 percent of the workforce). These data are drawn from social security registers and contain worker characteristics, such as age, sex, education, work experience, job tenure, occupation, occupational status (part-time, full-time, or apprentice workers), and average daily wages during an employment spell. As stating incorrect information incurs a penalty, the recorded wage data are very reliable. Above a contribution ceiling, however, wages are top-coded and need to be imputed.

Third, the LIAB contains administrative data on plants, such as the number of employees, the location, and the industry code. It is also possible to merge a subsample of the businesses with additional information from an annually conducted survey, the IAB Establishment Panel (EP).<sup>10</sup> In comprehensive interviews, the plants' managers provide precise information about the composition of the plant's workforce, revenues, investments, export share, and type of union coverage.<sup>11</sup> Since I merge annual information on plants with worker data, which are available on a daily level, I restrict all observations to yearly intervals to arrive at a consistent time scale.

Finally, one particular advantage of the LIAB is that occupational codes are classified according to the similarity of tasks on the job (Bundesagentur für Arbeit, 1998). Since its scheme *KldB88* is identical to the classification in the BIBB-IAB work survey, it is possible to assess a job's typical complexity akin to the procedure developed by Autor et al. (2003).

#### 2.2 Job complexity index

The job complexity index is intended to measure the heterogeneity of labor in the wage regression. By focusing exclusively on manufacturing, in which virtually all

<sup>&</sup>lt;sup>9</sup> The Research Data Centre provides access to LIAB for noncommercial research by confidential on-site and remote data access. See Heining et al. (2012) for a comprehensive overview of access possibilities. <sup>10</sup> The sample is disproportionately stratified according to establishment size. Accordingly, large plants

are oversampled, whereas sampling within each cell is random.

<sup>&</sup>lt;sup>11</sup> Some information is retrospectively reported in the survey. Thus, I forward impute those variables to obtain current values. Table B1 in the appendix gives a thorough overview of the data adjustments.

jobs are offshorable, this concept is associated with the comparative advantage in the production of goods and the regional specialization in particular tasks.<sup>12</sup>

The combined index has several advantages. In addition to featuring relatively high correlations with existing indices such as those developed by Spitz-Oener (2006), Baumgarten et al. (2013), Becker et al. (2013), and Brändle & Koch (2017), it includes not only the intensity of one job characteristic (e.g., routineness) but also detailed information on a variety of tasks and requirements.<sup>13</sup> By using a broad set of information, it is feasible to extract the variation of 243 occupations, which produces a decisive increase in the degrees of freedom in the subsequent analysis.

The data are drawn from the BIBB-IAB work surveys, which are jointly compiled by the Federal Institute for Vocational Education and Training and the IAB.<sup>14</sup> Approximately every six years, randomly selected workers from the German labor force answer questions about their abilities, performance requirements, professional qualifications and tasks on the job.<sup>15</sup> I utilize the two cross-sectional waves of 1998/99 and 2006 since they lie within the sample period and refer to the same population as the LIAB. Each wave covers 20,000 to 34,000 individuals.

The task complexity index applies a methodology similar to those of Becker et al. (2013) and Ottaviano et al. (2013). Therefore, the categories of interactive and nonroutine tasks are merged and extended with job performance requirements and necessary abilities. Table B2 in the appendix provides an overview of the various components.

In instancing interactive tasks or tasks that require many face-to-face interactions, cultural ties, or interpersonal skills, it is difficult to evaluate the tasks individually because, for example, collaboration with coworkers does not necessarily imply high complexity. Instead, various applications, such as dealing with consumer preferences, the legal system, various languages, and face-to-face interactions, may better approximate the human-capital requirements of a job.

Furthermore, performing many nonrepetitive tasks that require customized problem-solving ability is considered relatively complex. I assess nonroutine tasks based on whether young apprentices could perform these tasks independently in their first week of work. Since the survey questions about tasks are relatively broad, the nature of tasks may still vary substantially between occupations. The nonroutine

<sup>&</sup>lt;sup>12</sup> The concept of offshorability renders jobs non-offshorable when their underlying tasks require geographic proximity to consumers, which is inherent to the output of, e.g., taxi drivers, barbers, or construction workers. Conjointly, they can be attributed to the real estate industry and intangible outputs in the service sector. The manufacturing sector, however, comprises tangible outputs that are typically tradable. Consequently, in the context of offshoring the production of intermediate goods, the entire sphere of tasks could be performed abroad as long as a downstream production stage remains in the home country. This finding also implies that even some managers are susceptible to substitution by foreign labor.

<sup>&</sup>lt;sup>13</sup> Although Table C2 shows the similarity between complexity and the average skill level per occupation (from the BIBB-IAB work survey), it is named complexity to distinguish it from individual worker characteristics such as the highest degree attained (which is not recorded well in the LIAB).

<sup>&</sup>lt;sup>14</sup> I consider the BIBB-IAB work surveys to describe the job characteristics of German workers better than, e.g., O\*NET, since they involve a sample from the same population as the LIAB and since it employs the same occupational classification as the LIAB (no crosswalk required).

<sup>&</sup>lt;sup>15</sup> Cross-sectional waves are available for the years 1979, 1985/86, 1991/92, 1998/99, 2006, 2012, and 2018.

task "consult or inform", for instance, features high affirmative response rates by telephone operators, cashiers, auditors, and managers. Thus, the different kinds of seemingly identical tasks suggest a further distinction.<sup>16</sup>

To approximate quality, I consider information on the requirements for job performance and on certain skills or special/sensitive knowledge. Typically, the higher such requirements are, the more they foster regional specialization within (highwage) countries due to local knowledge spillovers, locally concentrated experience in certain tasks, and external economies of scale (Grossman & Rossi-Hansberg, 2012).

Consequently, I combine the degree of interactivity and nonroutineness of the job and the level of required abilities into a single complexity measure. To do so, I assign the responses of *each wave* to *four groups*, which differ with respect to the scaling and style of the survey questions.

In the 1998/1999 wave, the *first group* consisted of polar questions about the use of 81 workplace tools. Such tools range from machinery and diagnostic devices to computers, communication equipment, means of transport, and software. Whenever a worker reports having used a tool that is associated with a rather complex activity, this entry is marked.

In the 2006 wave, the questions in the *first group* are directly intended to capture the scope of nonroutine and interactive tasks. For example, workers state how often they present something or how often they have to solve new or unforeseen problems. The questions in the other three groups are similar in the two waves.

In the *second group*, the questions are intended to explore the frequency of 13 specific activities on the job. These are described, for instance, as repairing, consulting, educating, analyzing, or producing. The more frequently a worker performs any complex activity, such as consulting and educating, the higher the respective value is.

The *third group* comprises questions on specific abilities or knowledge. This includes, for example, any job that requires profound knowledge of the German legal system or high levels of English, German or any other particular foreign language skill.

In the *fourth group*, workers answer questions about performance requirements on the job, e.g., the frequency of having deadlines, whether mistakes lead to vast financial losses for the firm, or whether they have to improve techniques or processes.

To establish the comparability of the BIBB-IAB work survey and the LIAB, I consider only employees with social insurance who work more than 20 hours per week. For each of the eight task groups, I mark all affirmations of complexity before I separately sum them up per individual. In a second step, I average such sums over each 3-digit occupation. A higher mean indicates an occupation that (1) Is more likely to entail a larger number of different complex tasks, (2) Spends a larger share of its working time on the performance of complex tasks, and/or (3) Requires higher knowledge, skills, or abilities for its task set. Subsequently, I drop all occupations

<sup>&</sup>lt;sup>16</sup> For example, the use of a telephone may be nonroutine for a manager but fairly codifiable in a call center.

that encompass fewer than five individuals and normalize the remaining values by dividing the occupation averages by the maximum value of all means. The outcome is an index that ranges between zero and one for each of the eight groups.

I then separately sum up the four indexes per wave and normalize over all occupations to receive a single index for each of the two survey years. In a final step, I take the frequency-weighted average of the indices from the two waves (using the observations per occupation as weights) and obtain one static index for the analysis. A high value of the index is associated with a high relative input of human capital. While the simple combination of existing indices is an arguably arbitrary construction, it has the advantage of considering many task dimensions that are related to offshorability. Note also that the resulting ranking of occupations is highly correlated with existing indices and, most importantly, the average educational attainment per occupation (Table C2 in the appendix). Table 2 presents a list of occupations in manufacturing with the highest or lowest values of the task complexity index.

#### 2.3 Offshoring measure

The analyses use industry- or occupation-level offshoring measures, which are constructed in several steps. The starting point is the "narrow" definition of offshoring for manufacturing industries, as in Feenstra & Hanson (1996, 1999). Its construction considers imported inputs M that are produced in the same classification of economic activity  $j^*$  as the domestic using industry j (NACE/ISIC rev. 3). Hence, it contemplates firms' productivity decisions with respect to either producing those

Occupations (top $\rightarrow$ down)	Complexity	Occupations (lowest $\rightarrow$ up)	Complexity
Physicists, physics engineers, math- ematicians	1	Interior cleaning professionals	0.1468
Techn., vocational, factory instructors	0.9726	Machinery, container cleaners	0.2347
Entrepreneurs, directors, managers	0.9623	Rubber makers, processors	0.2707
Professional fire brigade	0.9525	Vehicle cleaners, servicers	0.2752
Chemists, chemical engineers	0.9312	Unskilled workers, roustabouts, helpers	0.2920
Manufacturing engineers, other	0.9292	Building laborers, building assistants	0.3289
Mechanical, motor engineers	0.9288	Pallet transporters, stockpickers, drivers	0.3368
Electrical engineers	0.9201	Tobacco preparers	0.3400
Engineers, other	0.9195	Upholsterers, mattress makers	0.3423
Economic and social scientists, statisticians	0.9089	Assistants for printing	0.3457

 Table 2
 The ten most and least complex occupations in manufacturing

Table 2 presents the occupations in manufacturing with the ten highest and lowest values of the task complexity index. Thereby, the left panel presents the occupations with the highest complexity ordered from top downwards. The right panel displays the most simple jobs ordered from the bottom upwards

inputs or importing them. These industry's imports are then normalized by its gross output *Y* in year *t*:

$$OS_{jt} = \frac{M_{jt}^{j^*}}{Y_{jt}}.$$
(1)

The offshoring measure  $OS_{jt}$  indicates the share of value added abroad that could, instead, be produced by the respective domestic industry. The data are drawn from the input-output tables of the German Federal Statistical Office, which is crucial for the analysis because it explicitly distinguishes between domestically and foreign-produced inputs (Winkler & Milberg, 2012, p. 40).

To arrive at region specific measures, I map the countries into groups with respect to their affiliation with a trade bloc, their geographic proximity, and the similarity of their economic structures. Thereby, I focus only on the most relevant offshoring destinations for Germany during the period considered because including more regions impedes the separate identification of the respective causal effects. These regions include the countries belonging to the former EU15 and the CEECs.

The offshoring measure  $OS_{jt}$  becomes region specific due to the weighting by the share of intra-industry imports from a particular region r in the total intra-industry imports of sector j in year t:

$$Ofs_{jtr} = \phi_{jtr} OS_{jt},\tag{2}$$

where

$$\phi_{jtr} = \frac{M_{jtr}^{j^*}}{M_{jt,World}^{j^*}}.$$
(3)

I draw the region specific data from the WIOT.

For the occupational exposures to offshoring, I weight the region-specific offshoring exposures of 24 industries  $Ofs_{jtr}$  by the number of workers in occupation q and industry j relative to the total number of employees in occupation q in manufacturing in 1995. This weighting yields 243 annual occupation-specific exposures to region-specific offshoring, which is insensitive to subsequent alterations in the composition of jobs across industries:

$$OccOfs_{qtr} = \sum_{j=1}^{J} \frac{L_{qj,1995}}{L_{q,1995}} Ofs_{jtr}.$$
(4)

In the Online Appendix B.3, I provide more technical details about the offshoring measure. Table C3 examines the summary statistics, and Table B1 provides more comprehensive details on the data processing.

Due to the consideration of intraindustry imports and occupational exposures, it is feasible to reveal how imparted tasks in intermediates impact the compensation of similar or dissimilar task sets in occupations.

# 3 Framework and empirical strategy

The theoretical literature identifies the various channels of offshoring that can affect labor demand (e.g., Groizard et al., 2014). In essence, the embodiment of these channels depends on a job's task profile. Although I adopt the idea of task trade as the trade of specific labor inputs, I do not attempt to disentangle the diverse channels at work; instead, similarly to Hummels et al. (2014), I utilize an estimable production function framework that describes the aggregate labor market effects of offshoring on different jobs.

#### 3.1 Estimation equation

The analysis contemplates linkages of domestic production with international value chains. Importing inputs substitutes for only a fraction of workers in the respective producing industry, while it complements the remaining workers in this industry.<sup>17</sup> Hence, it results in opposing effects within industries, where some occupations benefit and others lose. This reasoning indicates that industries are a well-suited unit for analyzing the ambivalent impacts of offshoring. However, to disentangle and quantify these counteracting effects in the home country, the exposure to imported inputs should be further partitioned into relevant task bundles. By including the occupation-weighted offshoring values from Eq. (4), it is straightforward to arrive at the occupational elasticities  $\beta_r$  and  $\beta_{R+r}$ , which capture cross-industry spillovers:

$$\ln w_{iqlt} = \sum_{r} \beta_{r} OccOfs_{qtr} + \sum_{r} \beta_{R+r} OccOfs_{qtr} \times CMPLX_{q}$$

$$+ \mathbf{x}_{it} \lambda + \gamma_{il} + \theta_{q} + \kappa_{lt} + \epsilon_{iqt},$$
(5)

where *r* indicates the region,  $r \in \{CEECs, EU15\}$ , and  $w_{iqlt}$  denotes the daily real wage of individual *i* in plant *l*, year *t*, and occupation *q*.<sup>18</sup> This equation is the baseline estimation for the analysis. It comprises three dimensions of fixed effects that account for unobserved heterogeneity. First, worker-plant fixed effects  $\gamma_{il}$  capture unobservable worker-plant-specific productivity. Second, occupation fixed effects  $\theta_q$  incorporate observable and unobservable time-invariant characteristics of occupations. This term also absorbs the explanatory power of  $CMPLX_q$ , whereas it is still possible to identify the interaction term with offshoring due to the variation in occupational exposure. Third, plant-year fixed effects  $\kappa_{lt}$  exhibit two important properties. On the one hand, they capture plant-specific shocks that are correlated with wages and offshoring, such as plant-specific technological

<sup>&</sup>lt;sup>17</sup> In contrast, importing final goods with no value added at home substitutes for workers in the respective producing industry, at least under the assumption that the country does not produce at the production possibility frontier and that the country is endowed with the respective technology.

<sup>&</sup>lt;sup>18</sup> I obtain real wages by deflating nominal values using the annual consumer price index that is provided by the German Federal Statistical Office. The daily real wage is then denoted in euros in year 2000-constant prices.

change. On the other hand, they avoid endogeneity concerns (with wages) since plant controls are multicollinear.<sup>19</sup>

Before estimating Eq. (5), I eliminate the effects of wage changes due to variations in working hours or gender-specific wage developments and reduce the unbalanced sample to full-time male employees in West Germany (excluding West Berlin).<sup>20</sup> Furthermore, the panel data consider only the best-paid spells in full time (excluding confounding overlaps of employment) in manufacturing (industries 15 - 37) on June 30 of each year from 1995 to 2007.

The LIAB reports the wage information of individuals up to the social insurance contribution ceiling, which yields 11 to 15 percent of top-coded employment spells per year.<sup>21</sup> Since the censored distribution biases the ordinary least squares (OLS) estimation, I either impute the missing values similarly to Card et al. (2013) (see the description in B.1.3) or cut off the sample at the 85th percentile of the wage distribution (85 percent sample). The latter renders attenuated estimates of the coefficients and variance (see Biørn, 2016) and therefore provides a lower bound of the absolute magnitude of the effects that need to be reaffirmed by other specifications due to the downward bias of the variance estimates.

# 3.2 Identification and instruments

Identifying the causal effect of offshoring on wages requires that endogeneity concerns be addressed. While offshoring affects wages, wages simultaneously affect the propensity to move associated tasks abroad, for example, if offshoring is more probable in high-wage industries or high-wage occupations due to higher potential cost savings.<sup>22</sup> Accordingly, the OLS estimates would be biased towards zero, because complex-task intensive inputs from the EU15 are expected to put pressure on the wages of especially those complex jobs that are better paid than other complex jobs (analogous for simple jobs and offshoring to the CEECs). I solve the endogeneity problem using an IV strategy, where time-varying and region-specific instruments must correlate with region-specific offshoring while being independent of wage setting in Germany.<sup>23</sup> In the selection of suitable instruments for  $OccOfs_{qtr}$ . I follow the work by Hummels et al. (2014) and consider the export supply of intra-industry

<sup>&</sup>lt;sup>19</sup> Other specifications incorporate time fixed effects  $\eta_t$  with and without a full set of plant controls to explore the beneficial productivity effect of offshoring.

<sup>&</sup>lt;sup>20</sup> The sample is unbalanced in the sense that individuals may drop out or enter the sample. For each year, however, a full set of covariates is included. If information is missing, the individual is excluded for this period. Moreover, singleton observations are iteratively dropped from the analysis (Correia, 2015). I run the regressions in Stata 14 utilizing the (iv)reghdfe command developed by Correia (2014).

<sup>&</sup>lt;sup>21</sup> The threshold is annually adjusted to the past wage trend (of the year t - 2).

<sup>&</sup>lt;sup>22</sup> Previous studies argue that this kind of simultaneity can be neglected because it is unlikely that individual daily wages substantially influence offshoring measured in industry or occupation aggregates Geishecker & Görg (2008). For the analysis at hand, however, a Wald test on the exogeneity of occupational exposure to region-specific offshoring is rejected, suggesting that simultaneity may still persist due to correlated wages within occupations.

<sup>&</sup>lt;sup>23</sup> These conditions exclude the exchange rate as a potential instrument, as it becomes fixed for many European countries with the introduction of the euro.

goods ESI from the respective offshoring destination r to other high-income economies HI<sup>.24</sup>

$$ESI_{qtr}^{HI} = \sum_{j=1}^{J} \frac{L_{qj,1995}}{L_{q,1995}} \frac{S_{jtr}^{HI}}{Y_{jtr}}, \text{ for each region } r.$$
(6)

Applying the weights from Eq. (4),  $L_{ai,1995}$  denotes the number of employees in occupation q and industry j in 1995 relative to the total number of manufacturing workers in occupation q,  $L_{q,1995}$ , in Germany.  $S_{jtr}^{HI}$  denotes the supply of intra-industry exports that are demanded by high-wage countries other than Germany, and  $Y_{iir}$ represents the output value of the respective foreign industry j. The trade data originate from the WIOT.<sup>25</sup>

To test the instrument invalidity (or any other misspecification), I add an overidentifying instrument akin to Baumgarten et al. (2013), namely, the ad valorem trade costs of shipping containers that Europe imports from China. Although maritime trade does not capture the modes of transportation for most goods within Europe, the costs of shipping containers still seem to exhibit high explanatory power for the other European transport costs. These costs thus comprise an eligible instrument because they are correlated with offshoring while being orthogonal to German wages.<sup>26</sup> Note, however, that shocks to transportation expenses not only lower the costs of imported inputs in Germany but also decrease the costs of German goods abroad. This phenomenon positively affects foreign demand and, consequently, the outcome variables of German plants, such as the export share, revenue, investment, or number of employees. In the baseline regression, I avoid the endogeneity of plant controls by including plant-year fixed effects, which also control for any shock within an industry that is not visible at the aggregate level. Therefore, they also account for the timing of offshoring activities and the introduction of new technology, which affect, e.g., the plant's number of employees, revenue, capital per worker, and task composition. The corresponding identifying assumption is that technology shocks affect wages in plants (or industries) but not at the occupation level.

This assumption raises concerns about unobservable skill-biased technological change and generally regards instrument validity, as precisely discussed in Autor et al. (2013). In essence, a (technology) shock that is common to all highincome countries may affect the demand for inputs to a similar extent. Therefore, if

$$ESI_{jtr}^{HI} = \frac{S_{jtr}^{HI}}{Y_{jtr}}.$$
(7)

<sup>&</sup>lt;sup>24</sup> The assignment to an income group follows the World Bank classification in 2000. Specifically, the other high-income economies consist of 23 countries in the WIOT: Australia, Belgium, Canada, Cyprus, Denmark, Spain, Finland, France, the United Kingdom, Greece, Ireland, Italy, Japan, South Korea, Luxembourg, Malta, the Netherlands, Portugal, Slovenia, Sweden, Taiwan, and the US. <sup>25</sup> Analogously, the industry-level offshoring measure is instrumented by

<sup>&</sup>lt;sup>26</sup> Ad valorem trade costs of shipping containers are extracted from the OECD: Maritime Transport Costs database (for methodology and data coverage, see Korinek, 2011). I map commodities denoted in 6-digit HS 1988 to ISIC rev. 3 at the 2-digit level using concordance tables provided by World Integrated Trade Solutions. Therefore, I weight trade costs for each commodity by its import value in 1995.

technology is simultaneously available to all high-income countries and correlates with both occupational wages in Germany and occupational exposure to offshoring in other high-income countries (the instruments), the IV estimates could still be biased. Although it is impossible to completely disentangle those effects, various specifications substantially mitigate confounders. First, the inclusion of plantyear fixed effects alleviates a potential bias since it implicitly considers the yearly plant-specific composition of workers, tasks and technology, such as computer use rates. The identified wage effects deviate from the average annual development in the plant. For instance, the simultaneous introduction of new technology would be controlled for by capturing the annual wage bill. In the specification with plant controls, the interaction of capital per worker and job complexity captures the channel of new technology on occupational wages. Second, the occupational exposures are weighted by initial worker shares per industry. This weighting creates an extra layer that mitigates the bias from technology if the other high-income countries feature a different worker-industry structure (different weighting in 1995) and if technology does not affect individual wages in Germany parallel to the sourcing of respective inputs *in* other high-income countries. Note that the latter condition describes the violation of the instrument validity (correlation of instruments with wages beyond offshoring from Germany).<sup>27</sup>

# 4 Results

This section begins by describing the links among industry characteristics prior to an increase in offshoring to either high- or low-wage countries and emphasizes the adjustments within plants that accompany such increases. The analysis then assesses the wage effect of industry or occupational exposure to offshoring.

# 4.1 Preliminary analysis: offshoring, industry characteristics, and plants' adjustments

Recalling the insights from Heckscher-Ohlin theory, low-wage countries, which are abundant in low-skilled labor, specialize and export simple task-intensive goods, whereas high-wage countries, where low-skilled labor is relatively scarce, export complex task-intensive goods. Furthermore, according to Grossman & Rossi-Hansberg (2012), the intra-industry trade between high-wage countries is explained by specialization in certain sets of tasks due to knowledge spillovers and scale economies. Table 3 shows how actual offshoring to two representatives of such regions correlates with plant-level outcomes in Germany. It provides insights on the initial characteristics of exposed industries and how these characteristics change when offshoring increases. Especially, columns 3–6 of panel B reveal changes in the quantitative dimension of relative labor supply, thus, the flip side of the estimates in the

<sup>&</sup>lt;sup>27</sup> An analogous reasoning as in this paragraph applies to confounding wage effects from a plant's exports.

	Cross-sectio	on, 1995	Panel, 199	6–2007		
	State FE and specific	d industry-	Plant FE a	Plant FE and industry-specific		
	Offshoring of in 2005	exposure	Offshoring	g exposure	Predicted of exposure	fshoring
	EU15	CEE	EU15	CEE	EU15	CEE
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Plant outcomes						
ln Wage bill	9.705***	22.833***	0.484	0.560	1.921	-0.591
ln Avg. wage	0.471	-0.292	0.041	4.504***	-3.096**	8.925***
In Employees	8.725***	24.566***	0.276	-4.170***	5.001***	-9.443***
In Capital per worker	7.024**	5.079	-4.485**	12.017	-13.114	33.732***
In Revenue	9.269***	16.230**	1.548*	7.752***	7.629***	10.553***
Exports (share)	2.096***	5.754***	-0.055	2.320***	-1.115	4.855***
Wage agreement: No	-0.464	-1.985***	-0.009	0.205***	-0.155*	0.350***
Plant level	-0.172	-1.725	0.021	0.034	-0.009	-0.042
Industry level	0.636	3.710***	-0.013	-0.234***	0.170**	-0.289***
Panel B: Worker tasks						
Simple job (D)	-1.369***	0.652	0.165*	-1.804***	2.798***	-2.859***
Medium-complexity job (D)	0.511*	-0.605	-0.038	-0.138	0.330	-0.150
Complex job (D)	0.857*	-0.047	-0.127	1.942***	-3.128***	3.010***
Panel C: Industry						
Domestic outsourcing	0.569***	-1.582***	-0.331*	-0.751**	1.750**	-1.097**

 Table 3
 Simple Regressions of Offshoring on Plant-Level Outcomes in Germany

Each *cell* is the estimate of a separate regression, where the dependent variable is listed in the same row and the explanatory variables are along the columns. Columns 1-2 show cross-sectional results from 1995 values on 2005 offshoring values. These results primarily indicate the characteristics of industries that subsequently offshored parts of production. For example, the first cell of the spreadsheet displays the coefficient of the (industry-state average of the) log wage bill per plant in 1995 on offshoring to the EU15 in 2005, i.e., 9.705. Columns 3 - 6 present how changes in plant- and worker-level variables move with changes in the exposure to offshoring. Note that in the presence of plant fixed effects, the influence of wage agreements can be determined only by changes in status. Standard errors are clustered at industry-year levels. Additionally, they are adjusted as in a two-stage regression in columns 3-6

p < 0.10, p < 0.05, p < 0.01

baseline regression in the next subsection.<sup>28</sup> Each *cell* represents a separate simple linear regression with firm-level outcomes as dependent variables regressed on industry-level offshoring. The correlations in columns 1 and 2 provide weak suggestive evidence on the initial industry characteristics that are followed by increases in offshoring. The main interest, however, is columns 5 and 6, which present the plant adjustments that come along with increases in offshoring.

<sup>&</sup>lt;sup>28</sup> For comparability reasons, the table is designed to be closely related to Table 3 of Hummels et al. (2014, p. 1612).

In columns 1 and 2 of panel A, I regress year-1995 industry averages of one plant outcome variable on industry-level offshoring in 2005 either to the CEECs or the EU15 (explanatory variable).<sup>2930</sup> Employing future values of offshoring (that include the treatment) on a cross-section primarily yields a level effect or initial characteristics of industries that are exposed to region-specific offshoring (vs. how they are affected). Additionally, state fixed effects account for regional differences among the German federal states. The coefficients suggest that offshoring takes place mainly in industries where plants have many employees, higher export shares, revenues, and wage bills and are covered by collective bargaining at the industry level. Note that all these characteristics are also typical of large and more productive firms (Melitz, 2003).

Each cell in columns 3–6 shows the estimate from a panel regression from 1996 to 2007 that includes plant fixed effects in addition to the single regressor.<sup>31</sup> The estimates present dependencies between changes in the outcome variables and changes in offshoring. Causality, however, is not inferred from the results. In contrast, the relationship may imply that the outcome variables determine offshoring, e.g., because plants with higher revenues can afford the costs of offshoring or offshoring determines the outcome variables, e.g., offshoring increases the revenues of plants. Alternatively, both could be true, and the variables would then be simultaneously determined due to reverse causality or due to any other shock to plants' demand or productivity and offshoring. These links are an integral part of the identification challenge and require consideration in the subsequent analysis. I mitigate this problem in columns 5 and 6 by predicting the values for the two types of offshoring using the instruments from Sect.  $3.2.^{32}$ 

The estimates suggest that the correlations vary substantially for predicted and non-predicted values of offshoring and between the two destination regions. Examining column 3, the intensity of offshoring to the EU15 (hereafter  $Ofs_{jt}^{EU15}$ ) and plant outcomes reveal hardly any distinct relationship. One of the few exceptions is capital per worker, which decreases with rising  $Ofs_{jt}^{EU15}$ , although revenues seem to increase. In contrast, the predicted values of  $Ofs_{jt}^{EU15}$  in column 5 show a more pronounced development. This finding may imply opposing causalities that influence the coefficients, for instance, if rising average wages lead to rising intensities of  $Ofs_{jt}^{EU15}$ , while rising intensities of  $Ofs_{jt}^{EU15}$  reduce the average wage within firms. The pre-

<sup>&</sup>lt;sup>29</sup> Similar to the procedure in Schank et al. (2007), capital per worker is approximated by the average of yearly investments in the three years prior to t, divided by the number of workers with social insurance in the firm. If the information is missing for at least two of the previous years, I drop the observation in year t.

<sup>&</sup>lt;sup>30</sup> In columns 1 and 2, the data for the wage bill, average wage, employees, revenue, and export share in the cross-section are drawn from the *Annual Report on Local Units in Manufacturing, Mining and Quarrying*, which is publicly available from the Federal Statistical Office. The data comprise state-level information on the universe of manufacturing plants in the West German federal states, therefore avoiding reliance on a weighted regression with weights from the EP. It is, however, not available for data on capital per worker and the wage agreement, which are thus extracted from the EP in the LIAB. I apply a weighted least squares estimation using the respective expansion factor for each stratus from the EP.

<sup>&</sup>lt;sup>31</sup> Table C4 in the appendix performs an analogous assessment for offshoring destinations outside of Europe and for domestic outsourcing.

<sup>&</sup>lt;sup>32</sup> I examine the first-stage regressions more comprehensively in Sect. 4.3.

dicted  $Ofs_{jt}^{EU15}$  exhibits positive impacts on revenues and employment, whereas the capital per worker tends to fall and average wages decline.<sup>33</sup> In general, these correlations suggest that rising  $Ofs_{jt}^{EU15}$  comes along with more labor-intensive production.

Columns 4 and 6 reveal that rising intensities of offshoring to the CEECs (hereafter  $Ofs_{jt}^{CEECs}$ ) are associated with growing revenues, increasing export shares, higher average wages, and more capital per worker. However,  $Ofs_{jt}^{CEECs}$  is also negatively correlated with the number of employees, while the plants' average wage bill does not show any significant correlation. Production thus appears to become more capital intensive. Combined with higher revenues, this finding suggests that  $Ofs_{jt}^{CEECs}$ occurs with boosts in the productivity of businesses, reductions in unit labor costs, and enhanced competitiveness, affirming the results of Dustmann et al. (2014).

Panel B explores the offshoring exposure of jobs with different degrees of complexity and how the share of these job groups correlates with offshoring. It estimates a linear probability model that regresses a binary variable, which indicates workers of the respective tercile of the task distribution, on the regional offshoring measures. Again, columns 1 and 2 show the estimates from a cross-sectional regression of workers in 1995 on future values of offshoring. The coefficients suggest that  $Ofs_{jt}^{EU15}$ takes place particularly in industries that intensively use medium-complexity and/or complex labor. Combined with the decreasing share of complex labor within plants in response to increases in  $Ofs_{jt}^{EU15}$  (columns 3 and 5), the correlations suggest a substitutability of imported inputs from the EU15 and complex task bundles, as well as a complementarity with simple labor. In contrast, future values of offshoring to the CEECs show no pronounced relation with the frequency of jobs in the various task terciles.<sup>34</sup> Over time, the expansion of imported inputs correlates positively with higher relative frequencies of complex jobs, suggesting either complementarity with complex labor or substitutability with simple labor.

# 4.2 The wage impact of industry exposure to offshoring

In an initial assessment, this section seeks to replicate related outcomes by Baumgarten et al. (2013) for comparison purposes. The starting point is Eq. (10), which employs the variation in industry exposure to imported inputs that complement or substitute for various jobs. Table 4 displays the estimated wage elasticities for the truncated 85 percent sample. Column 1 includes the aggregated measure of

<sup>&</sup>lt;sup>33</sup> Rising intensities of  $Ofs_{jt}^{EU15}$  are associated with changes in collective wage bargaining to agreements at the industry level, an expected outcome considering the growth of employment per plant. Note that their identification is limited to the few changes in status if plant fixed effects are present.

<sup>&</sup>lt;sup>34</sup> The indistinct exposures of jobs to  $Of_{j_{l}}^{SCEECs}$  are in line with earlier findings. Marin (2004), e.g., discovers that German affiliates in CEECs incorporate a relatively high share of skilled workers. Another intrafirm analysis by Becker et al., (2013, p. 100) finds insignificant impacts of offshoring to CEECs on the onshore wage bill share of workers in nonroutine and interactive jobs. In this regard, the CEECs are different from any other country group in the study.

	Dependent	variable: Log	daily wage			
	Fixed effect	s OLS		Instrumental va	ariables 2SLS	
	(1)	(2)	(3)	(4)	(5)	(6)
Offshoring expo- sure	-0.836***	-0.957***				
at industry level	(-5.65)	(-6.46)				
× job com- plexity	1.853***	2.358***				
	(8.63)	(10.66)				
Offshoring expo- sure			0.787***	1.559***	2.673***	
to EU15			(4.52)	(2.81)	(5.44)	
× job com- plexity			-1.484***	-2.475***	-4.907***	-4.075***
			(-5.86)	(-2.96)	(-5.57)	(-5.52)
Offshoring expo- sure			-4.550***	-4.494***	-3.956***	
to CEE			(-7.10)	(-5.84)	(-5.01)	
× job com- plexity			8.781***	12.29***	10.511***	8.142***
			(9.82)	(9.00)	(6.01)	(5.80)
Job complexity	-0.035	-0.002	0.081***	0.0906**	0.284***	0.275***
	(-0.14)	(-0.11)	(3.70)	(2.00)	(6.12)	(7.27)
Worker controls	Yes	Yes	Yes	Yes	Yes	Yes
Plant controls	Yes	No	Yes	Yes	No	No
Match FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	No	No	No	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	No
Observations	1,004,801	7,032,785	1,004,801	1,004,801	7,004,047	7,004,047
SW F-test				39.03; 23.89;	45.63; 31.90;	35.54; 142.35
				122.19 ; 93.82	86.56; 89.17	
Hansen J overid.				$\chi_1^2 = 1.579$ p=0.454	$\chi_1^2 = 2.980$ p=0.225	$\chi_1^2 = 1.084$ p=0.298

Table 4 Industry-Level Regression Results for the Truncated Sample

Table 4 shows the estimates for the regressions of daily real wages on industry-level offshoring and a set of worker controls and fixed effects. Columns 1–3 present the OLS results. Columns 4–6 display results from a two-stage least squares estimation, where offshoring is instrumented using  $ESI_{jir}^{HI}$ , ad valorem trade costs with China, and their interactions with the task index. The Sanderson-Windmeijer (SW) first-stage F-statistics (Sanderson & Windmeijer, 2016; Andrews et al., 2019) provide heuristic information about instrument strength in the presence of heteroskedasticity and multiple endogenous regressors. Including plant controls reduces the sample size due to data availability in the EP (columns 3 and 4). Robust *t* statistics are in parentheses. Standard errors are clustered according to Abadie et al. (2017) at industry-year levels, i.e., the treatment level

p < 0.10, p < 0.05, p < 0.01

offshoring  $OS_{jt}$  and a full set of worker and endogenous plant controls. The latter controls for industry-specific time trends that go beyond the industry fixed effects. Moreover, the specification includes match fixed effects and year fixed effects to control for time-invariant and unobserved heterogeneity in worker-plant matches and the time trend.<sup>35</sup> The offshoring term without interaction shows the wage effect for a virtual job that does not contain any complex tasks, while the associated interaction term indicates the wage changes along the complexity index. The coefficients confirm that performing more complex tasks shields the worker from adverse wage effects of offshoring. Their magnitudes, however, exceed the analogue in, for example, Baumgarten et al. (2013), which may be due to the higher homogeneity in their subsamples of high- and low-skilled workers or by employing match—instead of individual—fixed effects.

Column 2 omits endogenous plant controls and considers increased productivity due to offshoring as an additional channel. This raises revenues and capital per worker, which in turn increases wages. Compared to column 1, the coefficients become more pronounced and suggest an uneven distribution of the gains with respect to job complexity.

The output in column 3 distinguishes the origin of inputs as in Eq. (11). Notably, the coefficients of  $Ofs_{jt}^{CEECs}$  become larger in magnitude and statistical significance compared to the aggregated  $OS_{jt}$  in columns 1 and 2. It also becomes obvious that  $Ofs_{jt}^{EU15}$  features counteracting effects that are not visible in the estimates of  $OS_{jt}$ , demonstrating the heterogeneous wage effects described by theory and highlighting the importance of distinguishing not only the types of labor but also the types of inputs.

In columns 4–6, I run a two-stage least squares regression to remedy concerns about endogeneity. The instruments are the export supply of intermediate inputs from German offshoring destinations to high-income countries other than Germany  $ESI_{jtr}^{HI}$  (7) and ad valorem trade costs of shipping containers from China to Europe.<sup>36</sup> Because there is no statistic available to test the instrument strength in the presence of multiple endogenous regressors and heteroskedasticity (Andrews et al., 2019), I rely on a homoskedastic analogue, which are the Sanderson-Windmeijer (SW) F-statistics (Sanderson & Windmeijer, 2016).<sup>37</sup> These statistics indicate instrument strength in all 2SLS specifications in Table 4, while a Hanson test does not rule out instrument validity. The instruments are thus assumed to extract the exogenous variation in offshoring and its effect on wages. Compared to column 3, the coefficients become more pronounced, which is the assumed direction and suggests that reverse causality biases the coefficients opposing to the effects from offshoring. Therefore, relatively high wages of complex (simple) jobs lead to higher  $Ofs_{jt}^{EU15}(Ofs_{jt}^{CEECs})$  leads to decreasing relative wages of complex (simple)

<sup>&</sup>lt;sup>35</sup> Including plant-year fixed effects would render the offshoring variable perfectly collinear.

 $<sup>^{36}</sup>$  Following Wooldridge (2010), I replace the endogenous variable in the interaction terms with the instruments.

<sup>&</sup>lt;sup>37</sup> According to Andrews et al. (2019), I do not report Kleibergen-Paap or robust Cragg-Donald statistics because the 2SLS tests have the incorrect statistical size.

jobs. Column 5 then omits the plant controls, which yields estimates of offshoring that include the channels of increased productivity (e.g., through increasing revenues). This raises wage differences along the complexity distribution for  $Ofs_{jt}^{EU15}$ , while  $Ofs_{jt}^{CEECs}$  shifts upward with fewer wage differences between jobs of different complexity levels.

The specification in column 6 includes industry-year fixed effects, which absorb any shock at the industry level that is correlated with offshoring and thus also render other industry variables, such as  $Ofs_{jt}^{EU15}$  or  $Ofs_{jt}^{CEECs}$ , perfectly collinear. The interaction term, however, can still be identified as long as there exists within-industry-year variation in task composition. The estimates suggest even more diverse and highly significant wage effects of instrumented  $Ofs_{jt}^{EU15}$  along the task complexity index, while the influence of  $Ofs_{jt}^{CEECs}$  declines for high levels of job complexity.

The bottom line, however, remains that inputs from CEECs feature a much higher wage effect than inputs from the EU15. This disparity may be due to wage differences between Germany and the EU15 or CEECs and associated firm savings. Such productivity boosts would then foster the positive effect for complementary tasks and the negative effect for substitutable tasks and, hence, address job complexity. The larger the bundle of tasks is, the more protected the worker's total labor input against substitution by imported tasks in the form of intermediate goods. Hence, performing a larger variety of tasks makes it more likely that the worker will be able to compensate for substituted by specializing in other tasks. Regarding labor demand, this mechanism implies, on the one hand, lower (higher) onshore wage elasticities of jobs that are substituted by complex (simple) task-intensive imported inputs. On the other hand, demand shifts toward complementary tasks (to imports) may also result in shifts in the relative job frequency of complex jobs.

Recall that the industry level is important to observe the complementarity and substitutability of offshoring and domestic labor, but it is not necessarily the relevant wage-determining market. Instead, the occupation level seems to be a more suitable unit, since the estimated standard deviation of wages between (within) occupations is 0.1337 (0.2075) and 0.0790 (0.2344) between (within) industries.

#### 4.3 The wage impact of occupational exposure to offshoring

The analysis now turns to the baseline regression that analyzes the wage effects of occupation-specific exposures to offshoring. Columns 1–4 in Table 6 are associated with Eq. (5) and estimate wage changes within occupations and worker-plant matches, and relative to the annual plant averages. They do not include other channels emerging from labor demand changes, such as the impact of workers who switch occupations, employers/plants, or unemployment.

The specifications in columns 5–7 replace plant-year fixed effects with controls for plant changes over time and year fixed effects that capture changes driven by the business cycle. These adjustments also indicate whether plants' exports, or endowment of capital per worker, have heterogeneous wage effects with respect to job complexity. If this were the case, the plant-year fixed effect in the baseline

regression would not suffice to control for plant heterogeneity other than the effects from offshoring. While most plant-level controls yield wage impacts in accordance with economic theory, the coefficient of the export share in revenues is unexpected and reveals a negative influence. In the presence of spell fixed effects, the negative impact is supposedly associated with domestic demand shocks that affect wages and revenue at the same time. I cluster standard errors at the treatment level, as suggested by Abadie et al. (2017). This means that occupation-year levels account for the heterogeneity in the treatment effects.

In the OLS specifications, up to four endogenous variables remain in the equation: the two regional offshoring terms and their respective interactions with the task index. All 2SLS regressions instrument for them, including additional instruments for overidentification: the region-specific export supply of inputs to other highwage countries, ad valorem trade costs of shipping containers from China, and their interactions with complexity. The first-stage results  $(2 \times 4)$  in column 2 (and 6) are shown in Table 5 in the even- (odd-) numbered columns. While the baseline specification does not reject the validity of the overidentifying instruments, the specification with endogenous plant controls rejects a Hansen test, i.e., the orthogonality of the error term to regressors in the second-stage regression. This outcome is not surprising since the test is rejected not only if the overidentifying instruments are invalid but also if the model is incorrectly specified, as is the case with endogenous controls.

Examining the first stage in more detail, the coefficients demonstrate that all instruments exhibit a plausible influence on offshoring and that their impact is significant. Some of the coefficients, however, are less trivial to interpret. For example, the correlation of the export supply of the CEECs with exposure to offshoring to the EU15 is negative, which may imply that the latter is replaced because (suppliers from) the EU15 also offshore production to the CEECs. Its positive and significant interaction term shows that the relationship is less pronounced for complex jobs. Note that the reverse effect does not occur (columns 5 and 6), but the export supply of inputs from EU15 is positively correlated with offshoring to the CEECs. This effect, as described in Baumgarten et al. (2013), and Hummels et al. (2014), is the expected and could be related to trade costs that go beyond the cost of containers. The interacted container costs from China are positively correlated with offshoring to the EU15 and negatively correlated with offshoring to the CEECs. This combination may occur because Germany replaces complex task imports from the EU15 with imports from overseas if trade costs are low or because complex task imports from the EU15 react less sensitively to changes in container costs than other imports. Furthermore, I heuristically test for weak instruments following the procedure developed by Sanderson & Windmeijer (2016).<sup>38</sup> The results indicate that all instruments sufficiently explain the respective offshoring terms (instrument strength).

Predicting offshoring in the first stage thus incorporates exogenous variation in offshoring, which facilitates the identification of its causal effect on wages in the second stage. As columns 2 and 6 in Table 6 reveal (compared to columns 1 and 5),

 $<sup>^{38}</sup>$  It is a heuristic approach since the respective SW F-statistics assume homoskedasticity.

	Occupational offsl to EU15	horing exposure	× job complexity		Occupational offs to CEE	shoring exposure	× job complexity	
	(1)	(2)	(3)	(4)	(5)	(9)	(7)	(8)
Instruments								
Occup. export supply	$0.620^{***}$	$0.810^{***}$	0.106	0.161	$0.108^{***}$	0.073**	$0.137^{***}$	$0.123^{***}$
of inputs from EU15	(4.03)	(3.80)	(1.44)	(1.52)	(3.91)	(2.01)	(6.62)	(4.97)
× job complexity	-0.151	-0.329	$0.290^{***}$	$0.292^{**}$	$-0.309^{***}$	$-0.265^{***}$	$-0.322^{***}$	$-0.306^{***}$
	(-0.77)	(-1.29)	(2.75)	(2.19)	(-7.14)	(-4.83)	(-8.67)	(-7.08)
Occup. export supply	$-0.391^{***}$	$-0.196^{**}$	$-0.168^{***}$	-0.094**	$0.320^{***}$	$0.327^{***}$	$-0.059^{***}$	$-0.047^{***}$
of inputs from CEE	(06.7–)	(-2.24)	(-6.74)	(-2.13)	(26.44)	(17.43)	(-8.03)	(-4.60)
× job complexity	$0.197^{***}$	0.073	0.041	0.020	-0.024	$-0.063^{**}$	$0.406^{***}$	0.369***
	(2.87)	(0.77)	(1.02)	(0.42)	(-1.56)	(-2.48)	(36.21)	(22.24)
Occup. trade costs	0.007	0.016	0.011	0.018*	-0.001	0.007	-0.005**	0.001
	(0.52)	(0.81)	(1.29)	(1.67)	(-0.33)	(1.63)	(-2.03)	(0.39)
× job complexity	$0.049^{***}$	0.055**	0.023*	0.019	$-0.012^{**}$	$-0.021^{***}$	0.002	-0.005
	(2.77)	(2.09)	(1.95)	(1.24)	(-2.20)	(-2.75)	(0.60)	(-1.10)
Worker controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant controls	No	Yes	No	Yes	No	Yes	No	Yes
# of fixed effects								
Spell	973,034	240,386	973,034	240,386	973,034	240,386	973,034	240,386
Occupation	240	215	240	215	240	215	240	215
Year		12		12		12		12
Plant-year	145,072		145,072		145,072		145,072	

	Occupational c to EU15	offshoring exposure	× job complex	ity	Occupational to CEE	l offshoring exposure	× job complexi	ty
	(1)	(2)	(3)	(4)	(5)	(9)	(7)	(8)
Observations	6,828,208	1,004,804						
SW-F statistic	22.15	24.16	23.01	27.25	55.35	319.25	59.16	328.21
Table 5 reports the first-	-stage regression re	sults associated with	r columns 2 and	6 in Table 6. The	odd-numbered co	olumns are overidentified	ed using $ESI^{HI}_{qhr}$ , a	d valorem trade

OLS, which is caused by weak instruments and overidentifying restrictions. For the resulting specifications, the reported Sanderson-Windmeijer (SW) first-stage F-statistics reject weak identification (Sanderson & Windmeijer, 2016). Robust t statistics are in parentheses. Standard errors are clustered at occupation-year levels

p < 0.10, p < 0.05, p < 0.01, p < 0.01

Table 6 Regression results f	or the truncated wage	e distribution					
	Dep. variable: Log	g daily wage					
	STO	2SLS	OLS	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(9)	(2)
Occup. offshoring	0.493*	$2.016^{**}$	$1.022^{***}$		$1.163^{***}$	1.767*	5.646***
Exposure to EU15	(1.81)	(2.18)	(3.10)		(2.97)	(1.72)	(3.00)
x job complexity	$-0.962^{**}$	$-3.579^{**}$	$-1.633^{***}$		$-2.597^{***}$	-3.286*	$-4.161^{***}$
	(-2.13)	(-2.06)	(-3.00)		(-4.30)	(-1.72)	(-3.01)
Occup. offshoring	-8.322***	-7.885***		$-8.414^{***}$	-9.368***	-5.319***	-8.843***
Exposure to CEE	(-14.37)	(-10.51)		(-14.42)	(-9.31)	(-5.39)	(-2.72)
x job complexity	14.54***	$14.48^{***}$		$14.583^{***}$	$18.81^{***}$	$18.564^{***}$	$15.38^{***}$
	(17.43)	(15.10)		(17.39)	(15.04)	(15.90)	(9.05)
Worker controls							
Age <sup>2</sup>	-0.0261 ***	$-0.0261^{***}$	$-0.026^{***}$	$-0.026^{***}$	$-0.0310^{***}$	$-0.0306^{***}$	$-0.0299^{***}$
	(-40.76)	(-40.75)	(-41.19)	(-40.76)	(-36.05)	(-34.59)	(-42.38)
Tenure	$0.0062^{***}$	$0.0061^{***}$	$0.0061^{***}$	$0.006^{***}$	$0.0065^{***}$	$0.0067^{***}$	$0.0047^{***}$
	(53.67)	(53.76)	(50.35)	(53.68)	(17.09)	(17.50)	(31.05)
Tenure <sup>2</sup>	$-0.0176^{***}$	$-0.0176^{***}$	$-0.0173^{***}$	$-0.018^{***}$	$-0.0132^{***}$	$-0.0138^{***}$	$-0.0101^{***}$
	(-52.52)	(-52.48)	(-48.21)	(-52.21)	(-12.76)	(-13.36)	(-25.25)
Plant controls							
Exports (share)					$-0.0258^{**}$	$-0.0261^{**}$	
					(-2.43)	(-2.46)	
× job complexity					0.0149	0.0152	
					(0.94)	(0.95)	
In Capital per worker					0.0003	0.0007	
					(0.27)	(0.66)	

(continued)	
9	
e	
P	
ч	

	Dep. variable: I	og daily wage					
	OLS	2SLS	OLS	OLS	OLS	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(9)	(1)
× job complexity					0.0016	0.001	
					(1.09)	(0.70)	
ln Employees					0.0413 * * *	$0.0403^{***}$	
					(15.77)	(15.57)	
ln Revenue					$0.0187^{***}$	$0.0181^{***}$	
					(10.17)	(9.92)	
Wage Agreement: No							
Firm-level					0.0009	-0.0011	
					(0.46)	(0.57)	
Industry-level					0.0091 ***	0.0090***	
					(5.76)	(5.75)	
# of fixed effects:							
Spell	973,034	973,034	973,034	973,034	240,383	240,386	1,019,733
Occupation	240	240	240	240	215	215	240
Year					12	12	12
Plant-year	145,072	145,072	145,072	145,072			
Observations	6,828,230	6,828,230	6,828,230	6,828,230	1,004,801	1,004,801	7,032,802

Observations6,828,2306,828,2306,828,2306,828,2301,004,8017,032,802In columns 5 and 6, the omitted indicator dummy of the wage agreement indicates the comparable unit. An overidentification test confirms instrument validity  $(\chi_2^2=1.351, p=0.509)$  in column 2, whereas it rejects the test in column 6  $(\chi_2^2=16.076, p=0.000)$ . Robust *t* statistics are in parentheses. Standard errors are clustered at occupation-sear level.\* p < 0.10, \*\*p < 0.05, \*\*\*p < 0.01</td>

the elasticities of offshoring to the EU15 become more pronounced if endogeneity is removed. This change is as expected. It may be due to unobserved shocks that are positively (negatively) correlated with offshoring and have a negative (positive) effect on real wages (omitted variable bias) or—as assumed—reverse causality could cause bias the OLS estimates, e.g., if high wages of complex occupations induce more offshoring activities in the EU15. In contrast, the coefficients of offshoring to the CEECs change only slightly, suggesting a smaller bias due to endogeneity.<sup>39</sup>

Turning to the interpretation, the baseline regression in column 2 identifies the effects of offshoring to Eastern and Western Europe on wages within occupations, worker-plant matches, and plant-year observations. Specifically, the opposing signs for the two types of offshoring reveal, on the one hand, that both types incorporate substitution and productivity responses on wages and, on the other hand, that these responses show contrasting signs with respect to a job's complexity. While offshoring to the CEECs suggests positive effects on the relative wages of complex jobs, offshoring to the EU15 negatively affects the relative wages of complex jobs.<sup>40</sup> Although the latter is lower in magnitude, it is an important factor mitigating the relatively strong effects of offshoring to CEECs. Moreover, it is able to reconcile two seemingly contradictory phenomena in the literature: the high substitutability of complex jobs with foreign labor (offshorability) and the positive wage responses of those jobs observed in response to offshoring. While input trade among the EU15 accounts for the bulk of all offshoring activities and moderately lowers wages for complex jobs, the vast expansion of offshoring to CEECs dominates those effects and results in an overall wage divergence between jobs of different complexities.

To eliminate concerns that the opposing effects of region-specific offshoring are caused by multicollinearity, I separately run regressions for each type of offshoring (columns 3 and 4). These specifications, however, are likely to bias the coefficients due to the omitted variables. While the wage elasticity of offshoring to CEECs does not change, the elasticity of offshoring to EU15 countries becomes even more pronounced (compared to column 1). Multicollinearity is therefore unlikely to drive the coefficient signs.

Note that thus far, the specifications eliminate any channel of induced productivity on labor demand either by including plant-year fixed effects or plant controls (e.g., capturing wage increases due to higher revenues). By omitting these, wage elasticities include the productivity effect, which augments the wage impact of imported inputs from the EU15 (column 7), while the productivity effect of imported inputs from the CEECs does not seem to play an important role (similar

<sup>&</sup>lt;sup>39</sup> Table 3 shows in column 2 that neither a specific type of job nor the average wage is significantly correlated with future values of offshoring.

<sup>&</sup>lt;sup>40</sup> For example, the wage elasticity of offshoring to the CEECs amounts for a physics engineer (CMPLX = 1) to 6.595 (=  $\hat{\beta}_3 + \hat{\beta}_4 * 1$  when applying the estimates of column 2 in Table 6), while the elasticity of a metal grinder (CMPLX = 0.41) is negative, at -1.948. Thus, if the occupation-specific offshoring exposure increases by 0.01 percentage points, the wages of physics engineers who remained in their jobs increase by 6.6 percent, whereas the wages of metal grinders who remained in their jobs decrease by 1.9 percent on average.

to column 2). A possible explanation is that a plausible threat to offshore jobs to CEECs changes the bargaining position of workers more severely, which results in a lower labor share in overall income. Note also that in this setup, the coefficient of the interaction term does not exceed the EU15 offshoring term, implying positive average wage effects for complex jobs.

Figure 3 illustrates the baseline results from columns 2 (left, exclusive of the productivity effect) and 7 (right, including the productivity effect) by using the actual evolution of offshoring and by indexing real wages of simple (task = 0.2), medium-complexity (task = 0.5), and complex (task = 0.9) jobs to their values in 1996. Starting with the left graph, it depicts that offshoring to the CEECs increases, ceteris paribus, the average wages of complex jobs by 5.2 percent, while it reduces the average wages of simple jobs by 5.1 percent. If the effect of offshoring to the EU15 is now added, the overall impact of offshoring changes to +4.2 and -3.9 percent, respectively. Adding the productivity effect, the right graph indicates that the wage effects induced by offshoring to CEECs change only slightly; they still negatively (positively) affect workers with simple (complex) task profiles. If both types of offshoring are considered instead, the wage response shifts upwards for all types of workers. Note, however, that relatively simple jobs still suffer slight wage losses, while the discrepancy with the evolution of wages of complex jobs diminishes.

Thus far, wage regressions have incorporated information up to the 85th percentile of the wage distribution. They ignore truncation, which could affect the estimates for complex jobs, for example, if only a less productive subgroup of the respective occupation is observed. Then, their wages may grow more slowly or decrease more quickly than the actual group average. To obtain information on high wage earners, it is necessary to infer the effect from observable units. I do this in several ways.

As initial evidence, Table 3 (panel B) already indicates differences in labor market outcomes with respect to the type of offshoring and without any truncation. In summary, the correlations suggest that relative labor demand for complex jobs declines when inputs are imported from other high-wage countries and rises when inputs are imported from low-income countries.

In a second exercise, I impute censored entries following the procedure developed by Card et al. (2013) (see B.1.3) and rerun the main specifications from Table 6 on the full wage distribution. Table 7 presents the resulting OLS estimates, which feature the same signs but higher wage elasticities across the complexity distribution. This change is likely due to having a wider range of wages in the sample, which increases the deviations from the mean wage and the covariance with offshoring.<sup>41</sup> The previous tables therefore seem to present rather conservative estimates.

In another approach, I reduce the sample to workers younger than 35 years of age. Their wages are lower for reasons such as having less work experience and tenure, whereas they are not an occupational subgroup that features few productivity-enhancing individuals.<sup>42</sup> Selecting this subsample leaves 94 percent of the annual wage distribution non-censored. In comparison to the baseline regression, these

<sup>&</sup>lt;sup>41</sup> On the one hand, imputing wages provides conjectures on the behavior of high wage earners; on the other hand, it generates excessive noise for an instrumental variable approach.

<sup>&</sup>lt;sup>42</sup> The opposite is true, as suggested by the coefficients on the polynomial of tenure in Tables 4 and 6.



**Fig. 3** Wage responses to offshoring shocks by different task complexity sets. *Notes:* Fig. 3 depicts, ceteris paribus, the evolution of average wages of simple, intermediate, and complex jobs in response to offshoring 1) to the CEECs (thin line) or 2) to the CEECs and EU15 (thick line) from 1996 to 2007. The left panel draws on the estimates in column 2 in Table 6. It shows how offshoring to the EU15 mitigates the amplification of the income gap. The right panel refers to column 7 in Table 6. The evolution of wages now includes the channel of induced productivity from offshoring, where adding offshoring to the EU15 yields more positive wage effects on all types of jobs and a reduced income gap

	Dependent v	ariable: log d	laily wage			
	Imputed was sample	ges, full	Workers < 3	35 years, until	94th percenti	le
	OLS		OLS		2SLS	
	(1)	(2)	(3)	(4)	(5)	(6)
Occupational offshoring	2.043***	2.863***	1.433***	2.001***	3.362**	0.875
Exposure to EU15	(3.34)	(3.94)	(3.08)	(3.84)	(1.96)	(1.72)
× job complexity	-3.540***	-5.811***	-2.585***	-4.04***	-5.374**	-2.546
	(-3.48)	(-4.73)	(-3.46)	(-4.59)	(-2.00)	(-0.93)
Occupational offshoring	-17.609***	-18.78***	-16.49***	-15.40***	-16.34***	-12.41***
Exposure to CEE	(-17.92)	(-13.18)	(-12.32)	-8.04)	(-10.16)	(-7.13)
× job complexity	28.610***	34.37***	28.31***	30.27***	29.88***	33.05***
	(21.39)	(19.80)	(14.36)	(11.31)	(14.56)	(13.57)
Plant controls	No	Yes	No	Yes	No	Yes
Year FE	No	Yes	No	Yes	No	Yes
Plant-year FE	Yes	No	Yes	No	Yes	No
Observations	8,185,768	1,201,819	2,258,657	323,409	2,258,657	323,409
Hanson J					$\chi_2^2 = 1.584$	$\chi_2^2 = 20.418$
Overidentification					p = 0.453	p = 0.000

Table 7 Full Sample with Imputed Wages and the Subsample of Young Workers

Columns 1–2 show the results from the full sample (along the entire wage distribution) of male employees. Top-coded wages are imputed. Columns 4–8 display the results of workers younger than 35 years of age and up to the 94th percentile of the wage distribution (without top-coded entires). The IV regressions in columns 7–8 instrument the offshoring measures and their interactions with the task index. All specifications include a full set of worker controls and match and occupation fixed effects. Robust *t* statistics are in parentheses. Standard errors are clustered at occupation-year levels

p < 0.10, p < 0.05, p < 0.01, p < 0.01

specifications reveal more pronounced effects on relative wages, suggesting attenuation of the elasticities from the baseline regression.

# 5 Further robustness checks

The following section explores alternative specifications and assesses the robustness of the wage effects of offshoring.

# 5.1 Nonmonotone wage effects along the job complexity measure

The previous results assume a monotone relation between the offshoring terms and the task index and identify winners and losers for each type of offshoring. If offshoring positively affects the demand for some jobs and negatively affects that for others, the estimation assumes that the transition occurs at a given point. From the neighborhood around this point, the wage elasticity further increases towards the poles of the complexity distribution. Such behavior, however, could miss some information since the coefficient of the interaction term could also be driven by wage effects on either less- or more-complex jobs.

It is straightforward to put this possibility to the test by assigning each worker to one of five groups that constitute the quintiles of the complexity distribution. Online Appendix C.1 reports the results of this specification. It does not reject the assumption that the types of offshoring affect wages monotonically with respect to job complexity. Offshoring to the EU15 affects the wages of jobs with either few or many complex tasks. For offshoring to the CEECs, the expanded pattern of wage responses is clearer, revealing a substantial negative and significant impact on rather simple jobs and gradual increases for rather complex jobs.

# 5.2 The influence of labor market reforms in Germany

A major political debate in Germany persists regarding the economic impact of comprehensive labor market reforms that were introduced between 2003 and 2005, called the Hartz reforms. These reforms will bias the IV estimates if their impact is correlated with the occupational export supply of intermediate goods to other high-income countries and wage changes in Germany. Since the Hartz reforms were mainly intended to lower unemployment and the reservation wages of low-paid occupations, they may have had an adverse influence on the bargaining positions of simple jobs and thereby disturbed the causal identification of off-shoring in the above approach. To control for this development, I divide the sample into two periods.

Online Appendix C.2 shows the results for the two successive periods. The estimates suggest that the baseline results are not driven by confounding wage effects of the Hartz reforms.

# 5.3 Endogeneity of the job complexity index

Another potential threat to identification is the endogenous change of task profiles within occupations. Besides wages and employment, a potential channel through which offshoring impacts the labor market could be a job's adjustment in its typical task bundle. This adjustment could add new and potentially more complex (nonroutine) tasks unevenly across occupations. For example, a given assembly job could be increasingly involved in testing newly developed products or a given engineer job could be less involved in controlling production lines but rather in research and development or management. Any selective changes in the occupations' task profile may alter the rankings underlying the job complexity index and this in turn my cause a bias of the estimated coefficient on the wage effects. If one expects a selectivity that particularly those jobs become more complex that are exposed to high offshoring intensities, then the resulting ranking of occupations in the job complexity index would attenuate the magnitude of the estimated wage effect (e.g., some of the complex jobs may have had a more simple task profile before the sample period and vice versa). In a nutshell, the static complexity index used in the former analysis could be biased from the endogenous ranking of job complexity within the adjustment period. To provide insight on the magnitude of this bias, I thus run the same regressions from 2000 onward. I leave out the second wave of the BIBB-IAB work survey, so job complexity is now measured prior to the exposure to offshoring. As Online Appendix C.3 shows, the results from the baseline regression are robust and a rather conservative estimate of the true effects.

# 5.4 Alternative instrument

In Tables 4, 6 and 7, I report IV-estimates that use the ESI from Germany's offshoring destinations to other high-income countries. This choice of instruments is a trade-off between instrument strength, so the correlation between ESI and offshoring, and instrument validity, which is the conditional independence of the export supply to wage setting in Germany beyond the channel of offshoring. Thus far, I have decided in favor of the former, since the value chains within Europe feature high correlations. Choosing all high-income countries except for Germany, however, may lacks instrument validity, because the labor markets within Europe could also be interrelated beyond the channel of offshoring. Although it is likely that the multidimensional fixed effects capture most of the other potential channels, particularly time variant effects such as political reforms may still bias the IV-estimates. For this reason, in I now put even stronger emphasis on instrument validity and omit European countries from the measure of export supply of intermediate goods. The remaining high-income export destinations of the ESI are, hence, Australia, Canada, Japan and the USA (ESIAlt). I provide the technical details and results of this robustness test in Online Appendix C.4. They exhibit that the results are robust to using the alternative instrument.

#### 5.5 Alternative measures for offshoring

In the previous regressions, offshoring was defined by Eq. (1) as the fraction of imported inputs (from the same industry as the using industry) in the total output of the industry (similar to Baumgarten, Geishecker & Görg, 2013). This measure is designed to capture the importance of imported inputs and it is well suited to compare the international fragmentation of production across industries. Especially, it is able to account for an additional fragmentation of the value chain. However, it also comes with a drawback if applied to time series data, because it mechanically diminishes the effect of enhanced productivity from offshoring. Since this channel is expected to have positive effects on exposed workers' wages, the estimates in the previous regression could be downward biased. To test the magnitude of this bias, I apply an alternative measure for offshoring that considers the share of imported inputs in all inputs from the same industry as the using industry. Online Appendix C.5 documents the technical details and table of results. Overall, the patterns and relative magnitudes of the estimates remain similar to the baseline regressions.

#### 5.6 Alternative measures for task profiles

A final robustness check analyses whether the regression should rely on the tradability of tasks (offshorability) or any other particular characteristic. The selection ranges from a fairly similar index to the measure of routineness and, finally, to the measure of offshorability in Blinder & Krueger (2013). The technical details and results are reported in Online Appendix C.6. In summary, the results seem to be fairly robust to measures that closely measure occupational complexity.

# 6 Conclusion

The paper distinguishes types of labor by measuring the complexity of jobs. On the production side, it approximates the complexity of imports by considering offshoring to either high- or low-wage destinations. The empirical strategy then identifies wage effects with respect to job complexity and with respect to the type of imported inputs. Due to continuous reductions in European trade costs, the analysis of intra-European value chains is well suited to this subject. Using the most comprehensive dataset for workers in Germany allows the application of multidimensional fixed effects. This approach controls for much of the unobserved heterogeneity. The IV approach solves the problem of the endogenous determination of wages and offshoring by applying time-varying, region-specific instruments. With these tools at hand, the paper reveals wage changes within occupations and worker-plant matches that reach beyond plant-specific shocks.

The key insights of the paper are as follows. First, offshoring to high-income countries, such as the EU15, accounts for the bulk of Germany's imports in intermediate goods and rose substantially after 1996. In absolute terms, this increase is

comparable to the increase in offshoring to the CEECs. Second, the characteristics of offshoring destinations have substantially different implications for domestic production. Precisely, the analysis suggests that increasing offshoring to the EU15 entails more labor-intensive production, while increasing offshoring to the CEECs is accompanied by more capital-intensive production. Third, the analysis identifies the causal wage effects of offshoring to high- or low-income countries with respect to job complexity. Complex jobs moderately suffer from wage losses in response to offshoring to the EU15, whereas simple jobs experience wage gains. The paper also finds the opposite impacts for offshoring to the CEECs, and these impacts are of a much higher magnitude. Explicitly, the estimates suggest that offshoring to the CEECs increased the average wage of jobs with high complexity measures of 0.9 by 5.2 percent, while it decreased the average wage of jobs with low complexity measures of 0.2 by 5.1 percent between 1996 and 2007. If one also considers the growth of offshoring to the EU15, the corresponding wage effects are +4.2 and -3.9 percent, respectively.

Finally, the results can reconcile two seemingly contradictory phenomena in the literature: the high substitutability of complex jobs with foreign labor (offshorability) and the positive wage responses of those jobs to offshoring. While input trade among the EU15 accounts for the bulk of all offshoring activities and moderately lowers wages for complex jobs, the vast expansion of offshoring to CEECs dominates those effects and results in an overall wage divergence between jobs of different complexities. These counteracting effects of offshoring not only explain the low and often statistically nonsignificant labor market effects reported in the previous literature but also contribute to the recent debate on the effects of free trade agreements among high-income countries.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10290-022-00471-4.

Acknowledgements I greatly acknowledge the support of Nikolaus Wolf, Joachim Möller and Rolf Tschernig. I thank Gene Grossman, Esteban Rossi-Hansberg, Eduardo Morales, Oleg Itskhoki, and the participants at the trade seminar at Princeton University for their helpful comments. Princeton University's hospitality during my stay as a visiting researcher is highly appreciated. Johann Eppelsheimer generously provided the code for the wage imputations. Special thanks to my sister Jenny Koerner for her constant support. I thank the participants at the Workshop on International Trade and Labor Markets at the Institute for Labor Law and Industrial Relations in the European Union, the 10th Workshop on Perspectives on (Un-)Employment at the Institute for Employment Research, and the 20th Göttingen's Workshop for International Economic Relations, as well as Bernd Fitzenberger, Daniel Baumgarten, Michael Irlacher, Michael Koch, Christoph Rust, Stephan Huber, and two anonymous referees for their helpful comments. I am grateful for proofreading by Regal Johnson from the American Journal Experts.

Funding Information Open Access funding enabled and organized by Projekt DEAL. Not applicable.

Availability of data and material The LIAB mover model 9308 contains confidential information and can be accessed via a research stay at the IAB.

Code availability All estimations were programmed in Stata16. The codes are available upon request.

#### Declarations

Conflict of interest The authors declare no conflict of interest.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

# References

- Abadie, A., Athey, S., Imbens, G. W. & Wooldridge, J. (2017). 'When should you adjust standard errors for clustering?', National Bureau of Economic Research.
- Andrews, I., Stock, J. H., & Sun, L. (2019). Weak instruments in instrumental variables regression: Theory and practice. Annual Review of Economics, 11(1), 727–753.
- Autor, D. H., Dorn, D., & Hanson, G. H. (2013). The China syndrome: Local labor market effects of import competition in the United States. *American Economic Review*, 103(6), 2121–2168.
- Autor, D. H., & Handel, M. J. (2013). Putting tasks to the test: Human capital, job tasks, and wages. *Journal of Labor Economics*, 31(2), 59–96.
- Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. *The Quarterly Journal of Economics*, 118(4), 1279–1333.
- Baumgarten, D., Geishecker, I., & Görg, H. (2013). Offshoring, tasks, and the skill-wage pattern. European Economic Review, 61, 132–152.
- Baumgarten, D., Irlacher, M., & Koch, M. (2020). Offshoring and non-monotonic employment effects across industries in general equilibrium. *European Economic Review*, 130, 103583.
- Becker, S. O., Ekholm, K., & Muendler, M.-A. (2013). Offshoring and the onshore composition of tasks and skills. *Journal of International Economics*, 90(1), 91–106.
- Biørn, E. (2016). Econometrics of panel data: Methods and applications. Oxford University Press.
- Blinder, A. S. (2006). Offshoring: The next industrial revolution. Foreign Affairs, 85, 113.
- Blinder, A. S. (2009). How many us jobs might be offshorable? World Economics, 10(2), 41.
- Blinder, A. S., & Krueger, A. B. (2013). Alternative measures of offshorability: A survey approach. Journal of Labor Economics, 31(1), 97–128.
- Brändle, T., & Koch, A. (2017). Offshoring and outsourcing potentials: Evidence from German microlevel data. *The World Economy*, 40(9), 1775–1806.
- Bundesagentur für Arbeit. (1988). Klassifizierung der Berufe. Nürnberg: Systematisches und alphabetisches Verzeichnis der Berufsbenennungen.
- Card, D., Heining, J., & Kline, P. (2013). Workplace heterogeneity and the rise of West German wage inequality. *The Quarterly Journal of Economics*, 128(3), 967–1015.
- Carluccio, J., Cunat, A., Fadinger, H., & Fons-Rosen, C. (2019). Offshoring and skill-upgrading in French manufacturing. *Journal of International Economics*, 118, 138–159.
- Carstensen, K., & Toubal, F. (2004). Foreign direct investment in Central and Eastern European countries: A dynamic panel analysis. *Journal of Comparative Economics*, 32(1), 3–22.
- Correia, S. (2015). 'Singletons, cluster-robust standard errors and fixed effects: A bad mix'. Duke University.
- Dauth, W., Findeisen, S., & Suedekum, J. (2014). The rise of the East and the Far East: German labor markets and trade integration. *Journal of the European Economic Association*, 12(6), 1643–1675.

- Dauth, W., Findeisen, S., & Suedekum, J. (2021). Adjusting to globalization in Germany. Journal of Labor Economics, 39(1), 263–302.
- Dustmann, C., Fitzenberger, B., Schönberg, U., & Spitz-Oener, A. (2014). From sick man of Europe to economic superstar: Germany's resurgent economy. *Journal of Economic Perspectives*, 28(1), 167–88.
- Dustmann, C., Ludsteck, J., & Schönberg, U. (2009). Revisiting the German wage structure. The Quarterly Journal of Economics, 124(2), 843–881.
- Ebenstein, A., Harrison, A., McMillan, M., & Phillips, S. (2014). Estimating the impact of trade and offshoring on American workers using the current population surveys. *Review of Economics and Statistics*, 96(4), 581–595.
- Eberle, J., Jacobebbinghaus, P., Ludsteck, J., & Witter, J. (2011). Generation of time-consistent industry codes in the face of classification changes: Simple heuristic based on the establishment history panel, FDZ Methodenreport 2011/5. Nuremberg: Institute for Employment Research.
- Economist (2004), 'Germany on the mend', November 17. http:// www.economist.com /node /3352024.
- Eppinger, P. S. (2019). Service offshoring and firm employment. Journal of International Economics, 117, 209–228.
- Feenstra, R. C., & Hanson, G. H. (1996). Globalization, outsourcing, and wage inequality. American Economic Review, 86(2), 240–245.
- Feenstra, R. C., & Hanson, G. H. (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.
- Fischer, G., Janik, F., Müller, D. & Schmucker, A. (2008). 'The IAB Establishment Panel: From sample to survey to projection', *FDZ Methodenreport* 1(2008).
- Fitzenberger, B., Osikominu, A., & Völter, R. (2006). Imputation rules to improve the education variable in the IAB employment subsample. *Schmollers Jahrbuch: Journal of Applied Social Science Studies/Zeitschrift für Wirtschafts-und Sozialwissenschaften*, 126(3), 405–436.
- Gartner, H. (2005). The imputation of wages above the contribution limit with the German IAB employment sample. *FDZ Methodenreport*, 2(2005), 2005.
- Gathmann, C., & Schönberg, U. (2010). How general is human capital? A task-based approach. *Journal* of Labor Economics, 28(1), 1–49.
- Geishecker, I., & Görg, H. (2008). Winners and losers: A micro-level analysis of international outsourcing and wages. *Canadian Journal of Economics*, 41(1), 243–270.
- Gernandt, J., & Pfeiffer, F. (2007). Rising wage inequality in Germany. Journal of Economics and Statistics, 227(4), 358–380.
- Goos, M., Manning, A., & Salomons, A. (2014). Explaining job polarization: Routine-biased technological change and offshoring. *American Economic Review*, 104(8), 2509–26.
- Groizard, J. L., Ranjan, P., & Rodriguez-Lopez, A. (2014). Offshoring and jobs: The myriad channels of influence. *European Economic Review*, 72, 221–239.
- Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading tasks: A simple theory of offshoring. American Economic Review, 98(5), 1978–1997.
- Grossman, G. M., & Rossi-Hansberg, E. (2012). Task trade between similar countries. *Econometrica*, 80(2), 593–629.
- Heining, J., Jacobebbinghaus, P., Scholz, T., Seth, S., et al. (2012). Linked-employer-employee data from the IAB: LIAB-Mover-Model 1993–2008 (LIAB MM 9308). *FDZ-Datenreport*, 1, 2012.
- Hummels, D., Jørgensen, R., Munch, J., & Xiang, C. (2014). The wage effects of offshoring: Evidence from Danish matched worker-firm data. *American Economic Review*, 104(6), 1597–1629.
- Hummels, D., Munch, J. R., & Xiang, C. (2018). Offshoring and labor markets. *Journal of Economic Literature*, 56(3), 981–1028.
- Johnson, R. C., & Noguera, G. (2017). A portrait of trade in value-added over four decades. *The Review of Economics and Statistics*, 99(5), 896–911.
- Korinek, J. (2011). Clarifying trade costs in maritime transport. OECD: Working party of the trade committee.
- Krishna, P., Poole, J. P., & Senses, M. Z. (2014). Wage effects of trade reform with endogenous worker mobility. *Journal of International Economics*, 93(2), 239–252.
- Krugman, P. R. (2000). Technology, trade and factor prices. Journal of International Economics, 50(1), 51–71.
- Marin, D. (2004). 'A nation of poets and thinkers' less so with Eastern Enlargement? Austria and Germany', CEPR Discussion Paper 4358. London

- Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6), 1695–1725.
- Mion, G., & Zhu, L. (2013). Import competition from and offshoring to china: A curse or blessing for firms? *Journal of International Economics*, 89(1), 202–215.
- Moser, C., Urban, D., & Weder Di Mauro, B. (2015). On the heterogeneous employment effects of offshoring: Identifying productivity and downsizing channels. *Economic Inquiry*, 53(1), 220–239.
- Ottaviano, G. I. P., Peri, G., & Wright, G. C. (2013). Immigration, offshoring, and American jobs. American Economic Review, 103(5), 1925–59.
- Sanderson, E., & Windmeijer, F. (2016). A weak instrument F-test in linear IV models with multiple endogenous variables. *Journal of Econometrics*, 190(2), 212–221.
- Schank, T., Schnabel, C., & Wagner, J. (2007). Do exporters really pay higher wages? First evidence from German linked employer-employee data. *Journal of International Economics*, 72(1), 52–74.
- Spitz-Oener, A. (2006). Technical change, job tasks, and rising educational demands: Looking outside the wage structure. *Journal of Labor Economics*, 24(2), 235–270.
- Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & Vries, G. J. (2015). An illustrated user guide to the world input-output database: The case of global automotive production. *Review of International Economics*, 23(3), 575–605.
- Winkler, D. (2010). Services offshoring and its impact on productivity and employment: Evidence from Germany, 1995–2006. *The World Economy*, 33(12), 1672–1701.
- Winkler, D., & Milberg, W. (2012). Bias in the proportionality assumption used in the measurement of offshoring. World Economics, 13(4), 39–60.
- Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data. Cambridge, MA: MIT press.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.