Economics and Business Review, Vol. 2 (16), No. 3, 2016: 99–120
DOI: 10.18559/ebr.2016.3.7

Quantifying wage effects of offshoring: import- *versus* export-based measures of production fragmentation[1]

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Abstract: In this paper we examine the implications of international fragmentation of production on wages in the light of recent methodological developments in offshoring measurement. In particular, we compare the results stemming from two ways of quantifying offshoring – the traditional one based on import statistics and the one obtained from the decomposition of gross exports and input-output information.

In the empirical part of our study, we estimate the extended version of wage equation, rooted in the Ricardian model of skills, tasks and technologies where skill specific wages are explained by industry-specific measures of capital, skill supply and offshoring indices. The analysis is performed for a large panel (40 countries, 1995–2011 and 13 manufacturing industries). The results of the FE setting indicate that regardless the way offshoring is measured it is negatively associated with wages. However, when the endogeneity is accounted for, this negative association is sustained only for the export-based measures.

Keywords: wage, offshoring, input-output, export decomposition.

JEL codes: F14, F16, F66, C67.

Introduction

In this paper we examine the implications of international fragmentation of production on wages in the light of recent methodological developments in offshoring measurement. In particular, we compare the results stemming from two ways of quantifying cross-border production sharing: the traditional one

[1] Article received 21 April 2016, accepted 5 August 2016. The research has been conducted within the project financed by the National Science Centre (NCN), Poland (decision number DEC-2013/11/B/HS4/02134). We would like to thank two anonymous referees, as well as the participants of the Conference on Applications of Mathematics and Informatics in Economics (Poznań University of Economics, April 2016) for valuable comments.

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based on import statistics and the one obtained from the decomposition of gross exports and input-output information.

Offshoring (called also foreign or international outsourcing) reflects the fragmentation of the production process into parts and refers to "*geographic separation of activities involved in producing a good (or service) across two or more countries*" [Feenstra 2016: 83]. Traditionally, offshoring activity at the sectoral level has been measured as the ratio of imported intermediate inputs to the value added of the sector in which they are used [Feenstra and Hanson 1999]. In our paper we go beyond this crude proxy and present the application of a new generation of indices. They are obtained through Wang, Wei, and Zhu [2013] decomposition of gross trade flows, applied to global value chains (GVC) analysis. In particular, we treat the information on foreign value added (FVA) in gross exports as the alternative proxy of country's involvement in production sharing and offshoring.

We apply these two types of offshoring measures to test the impact of production relocation abroad on wages in domestic sectors. Theoretical fundamentals are provided by the recent stream of international economics' literature which developed in response to the observed tendencies of increased relocation of production abroad [among others: Grossman and Rossi-Hansberg 2008; Baldwin and Robert-Nicoud 2014]. According to trade-in-tasks theory, the relocation of more routine activities overseas can endanger domestic low skilled (production, manual) workers and favor high-skilled workers performing non-routine tasks.

In the empirical part of our study, we estimate the extended version of wage equation, rooted in the Ricardian model of skills, tasks and technologies. Wages of different skill categories of workers are determined by industry-specific measures of capital, skill supply and offshoring and controlled for country-specific labour market conditions. In alternative specifications we employ import- and export-based measures of offshoring to assess if the way of its measurement matters for the conclusions on wage effects of global production sharing. The analysis is performed for a large panel (40 countries, 1995–2011) of three dimensional identification: country-sector-time. We check if the impact of offshoring on wages differs across workers by considering the breakdown of sectoral labor force into three skill groups (low, medium and high-skilled).

The structure of our paper is as follows: in Section 1 we present the theoretical background together with the literature review of related sector-level empirical studies on wage-offshoring nexus. In Section 2, we present our data and crucial descriptive statistics on the trends in offshoring in the analyzed period. In particular, we confront the evidence based on traditional offshoring indices with the ones based on global value chains' analysis. The results of the empirical model estimation are presented in Section 3. Finally, Section 4 concludes. The contribution of our study relies mainly in showing that even though the two measures are highly correlated, the way of offshoring measurement can alter the conclusions drawn. In particular, we show that the conceptualization of production fragmentation and the way it is measured is crucial in a setting accounting for endogeneity between production sharing and wages.

1. Related literature and theoretical background

There are several streams of labour economics literature related to wage determination process [Cahuc et al. 2014]. In particular, we can refer to such aspects as: the interplay between skill demand and supply, wage effects of the assignment of skills to tasks; job and wage polarisation; relations between worker and employer in the presence of imperfect competition on labour markets; decentralisation of wage bargaining; collective bargaining and the role of labour unions; the evolution of participation rates, part-time work and other factors affecting labour supply.

We relate our empirical analysis to the theoretical model proposed by Acemoglu and Autor [2011: 1096–1147] which belongs to a class of Ricardian-type models in which wages are linked to comparative advantage of workers performing specific tasks. Acemoglu and Autor [2011] consider three types of labour: low, medium and high-skilled who perform different types of tasks: manual, routine and the most advanced, non-routine activities which are performed by workers with the highest skills. At the same time, there is capital-labour substitution of some parts of the production activity and some tasks can be relocated abroad (e.g. through offshoring). A relocation decision results from a cost-benefit analysis. It is based on the confrontation of the costs of relocation and the costs of combining tasks performed at distinct locations into the final product with the benefits of having access to lower labour costs or cheaper intermediate inputs. The new technology (e.g. ICT) lowers the cost of production fragmentation increasing offshoring intensity which further shifts negatively the demand for workers whose tasks have been displaced. The demand shift can result either in the job loss or in a wage drop. The later effect should be especially relevant in the short-run, for instance when workers are immobile across borders and industries.

The skill-specific wages in this model are determined by: labour supply of workers with different skills (L_s), their productivity (A_s) and the intensity of offshoring in the sector (*Off*). We do not assume *a priori* which tasks (skilled or unskilled labour intensive) are more likely to be offshored and we perform the analysis for three distinct skill categories, so s ={high, medium, low}.

In the empirical literature, the theme of wage effects of offshoring has already a long tradition.[3] Given the nature of the date we use (see Section 2), we will

[3] Feenstra [2016, Chapter 4] provides a comprehensive review of the theoretical and empirical findings on the relationship between trade in intermediate inputs and wages.

concentrate here on wider industry-level panel data studies, putting aside micro level analysis based on the data for individual workers. Our study is closer to a few existing studies (albeit limited in country cover and/or time span) on wage responses to offshoring, performed at the industry level. Polgár and Wörz [2010] address the link between trade and wages in 15 manufacturing and 6 services sectors in 25 EU countries (1995–2005) but they do not discriminate between the wages of distinct skill categories of employees (as we do). Some recently published sector-level studies do take into account skill heterogeneity. Michaels, Natraj, and Van Reenen [2014] draw on EUKLEMS industry-level data (of which the WIOD, which we use, is a substantial extension) for nine Western European countries (plus Japan and the US), focusing on the wage bill shares of workers from groups of different education level, and confirm an ICT-based polarization hypothesis. In a complementary study, Foster-McGregor, Stehrer, and de Vries [2013] employ WIOD data (40 countries, 1995–2009) to analyze changes in labour demand as a result of offshoring (medium-skilled workers are found to suffer the most in terms of shrinking labour demand; similar effects are documented in [Timmer et al. 2013]). Finally, Parteka and Wolszczak-Derlacz [2015] perform the analysis of wage convergence across EU27 countries and study whether offshoring can have the potential impact of the wage equalisation across manufacturing sectors of European countries. They find that offshoring reduces the wage growth of domestic medium- and low-skilled workers, however this negative effect is economically small and additionally international outsourcing plays a negligible role in wage equalization.

In these studies offshoring activity is measured in a traditional way as the ratio of imported intermediate inputs to the value added of the sector in which they are used. Such an approach follows the tradition adopted by the first wave of research on global fragmentation of production [among others: Feenstra and Hanson 1999; Hijzen and Swaim 2007]. However, it has been argued that measures based on information on imports of intermediate inputs should be treated as a crude proxies of production segmentation. Goods tend to cross borders multiple times and the value is added at different stages of production process in different countries.

Consequently, recently, the supply chain literature, dealing with so called "trade in value added", has been developing rapidly, proposing new ways of measuring value added trade (see [Mattoo, Wang, and Wei 2013] for a thorough review).[4] Its origins go back to the notion of vertical specialization (understood as „the use of imported inputs in producing goods that are exported" [Hummels, Ishii, and Yi 2001]. The efforts have been made to measure foreign content (foreign value added) in country's exports. Hummels, Ishii, and Yi

[4] In the Polish literature the description of recent trends in value added trade and production fragmentation measurement can be found in, among others: Ambroziak [2013], Białowąs [2013a, 2013b] or Radło [2014].

[2001] proposed to use input-output (IO) tables to decompose country's exports into shares corresponding to domestic and foreign value-added. Johnson and Noguera [2012] combined bilateral trade data and input–output data to measure value-added exports (VAX) to gross export ratio (called the VAX ratio).

The computation of input-output tables for several economies within the WIOD project [Dietzenbacher et.al. 2013; Timmer et al. 2015] facilitated further empirical work on the split of value added across countries. Using WIOD data, Koopman, Wang, and Wei [2014] proposed more elaborated decomposition of gross exports into various components. They integrated all previous measures of vertical specialization and value-added trade into a unified framework, identifying double counted terms in official trade statistics. Bilateral sector level applications of such an approach were introduced by Wang, Wei and Zhu (subsequently referred to as WWZ: [Wang, Wei, and Zhu 2013]). Their decomposition takes into account backward and forward linkages and can be used to precisely locate a particular sector in an international production chain that takes into account both international and domestic production sharing.

In our empirical analysis we will compare the results obtained with the use of traditional offshoring indices in the spirit of Feenstra (based on information on imports) with the ones using WWZ decomposition of value added into domestic and foreign components (applied to gross exports).[5]

2. Data and descriptive statistics

2.1. Data

Our main data source is World Input Output Database (WIOD) which consists of WIOD's Socio-Economic Accounts and World Input Output Tables (it is downloadable at: www.wiod.org). From Socio-Economic Accounts we obtain information on labour compensation and hours worked used to calculate hourly wages paid in each sector (overall and for three categories of workers: high, medium and low skilled).[6] For those countries for which the nominal variables are originally expressed in national currencies, we use the bilateral exchange rates from the Penn World Table [PWT 8.1; Feenstra, Inklaar, and Timmer 2015] to put all wages into dollars. Additionally, from WIOD's Socio-Economic Accounts we get several sector-specific characteristics, such as: industrial output, components of value added, capital stock, and labour abundance (hours worked – overall and by skill type). The original data has the panel structure of 40 countries and the rest of the world (RoW), and is disaggregated

[5] To obtain WWZ decomposition we use *decompr* package in R [Quast and Kummritz 2015].

[6] In WIOD skills are defined here on the basis of educational attainment. High skilled workers correspond to those with academic education, medium skilled to upper secondary education graduates and low skilled to individuals with primary education only.

into 35 industries observed in the period 1995–2011.[7] We limit our analysis to 13 manufacturing sectors for which the statistics on production sharing are more commonly analysed. In Table A1 and Table A2 in the Appendix we list the analysed countries and sectors.

Control variables describing countries' labour market conditions come either from World Bank's WDI (e.g. country level unemployment rate) or from Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts, (ICTWSS) Version 5.0., University of Amsterdam. We consider here the variables describing country's wage-setting mechanism (e.g. degree, type and level of its coordination, from uncoordinated bargaining to state-imposed bargaining, from bargaining predominantly taking place at the local or company level to bargaining taking place at central or cross-industry level) and union density.[8]

Finally, the offshoring indices (both import- and export-based) are calculated through the utilisation of the data coming from World Input Output Tables (WIOT). WIOT is constructed from national supply and use tables which are linked across countries through detailed information on bilateral international trade flows. Each product (good or service) can be produced either by a domestic industry or by a foreign industry. For a given country, flows of products destined both for intermediate and final use are split into domestically produced or imported. In the latter case there is also additional information on the foreign industry from which the product is coming. The total use of each product encompasses intermediate use, final use (private or government consumption and investment) and exports. The detailed information on the construction of WIOT can be found in Dietzenbacher et al. [2013] and in Timmer et. al. [2015].

Using these data we firstly compute a traditional measure of offshoring (*Off_imp*): the ratio of imported intermediate inputs (in a broad sense, thus we consider inputs coming from all foreign industries[9]) to the value added of the sector where they are used:

$$Off\_imp_{ijt} = \frac{impI_{ijt}}{VA_{ijt}}, \tag{1}$$

[7] The recent release goes back to November 2013 and since then the data has not been updated. We are constrained to limit the time span till 2009 because this is the last year for which information needed for calculation of wages of different skill groups of workers is available. To the best of our knowledge there is no other source of more recent sector level input-output data which could be used for and extensive analysis of offshoring-wages nexus.

[8] All variables included in ICTWSS database, along with the methodology of their derivation, is explained thoroughly in: [Visser 2015].

[9] Alternatively, the denominator can consider only purchases of inputs belonging to the same industry in which they are used – such a measure reflects so-called narrow (or, intra-industry) offshoring. See Feenstra and Hanson [1999] or Hijzen and Swaim [2007] for an application. However, as the latter authors point out, such a narrow measurement of offshoring is sensitive to sectors' classification.

where:

i – denotes domestic sector,

j – refers to country,

t – denotes the time period (year),

impI – stands for imported inputs (imported intermediates),

VA – the value added.

Although the measure presented in (1) has a long tradition of application in empirical studies on offshoring, it clearly has many shortcomings and as such can be treated only as a crude proxy of production relocation. First of all, it includes imports of *all* intermediate inputs, also those which cannot be produced domestically (or are unavailable, e.g. raw materials) and as such must be purchased abroad. If imports of some intermediate inputs are due to the fact that their production outlies the specialisation of local companies, they do not substitute for native labor. Additionally, as noticed by Hummels et al. [2014], imports of machinery can influence wages of local workers. They embody access to foreign technology rather than reflect pure offshoring and without very detailed disaggregation of the data (e.g. machinery *versus* its parts) this is difficult to be distinguished. Finally, limiting offshoring to intermediate inputs only also can be oversimplified because it ignores offshoring of the final stage of production process [Michel and Rycx 2012]. Castellani, De Benedictis, and Horgos [2013: 160] even argue that "we should not really trust offshoring indices, when being calculated in a traditional way". They however have the advantage of being easily obtainable when import data split into final and intermediate products is at hand.

Some of the abovementioned problems can be mitigated by indices obtained through WWZ decomposition. WIOT contains data where trade information (imported intermediate inputs used to calculate 'old' offshoring indices) are expressed in total gross trade flows. They do not show what part was added in the supplying industry and what part in previous stages of production and in foreign countries. WWZ decomposition method can be used to overcome this issue. Specifically, we decompose gross export (*EXP*) into main four components: domestic value-added absorbed abroad (*DVA*), value-added first exported but eventually returned home (*RDV*), foreign value-added (*FVA*) and pure double counted terms (*PDC*):[10]

$$EXP = DVA + RDV + FVA + PDC. \tag{2}$$

PDC can be due to pure double counting from foreign sources (*FDC*) or domestic ones (*DDC*). It should be noted that the sum of *FVA* and *FDC* gives

[10] For the simplification we omit here the sector subscript. For a detail derivation of the decomposition for the country aggregate level, country-sector level, bilateral aggregate level and bilateral-sector level see Appendix of Wang, Wei, and Zhu [2013].

the measure of vertical specialization (*VS*) which was traditionally presented in the literature [among others: Hummels, Ishii, and Yi 2001] as foreign content in a country's gross exports.

We are going to treat the information on the ratio of foreign value added (*FVA)* to sectoral value added as an alternative measure of offshoring and dependence of domestic sector on foreign production, hence (*Off_exp*):

$$Off\_exp_{ijt} = \frac{FVA_{ijt}}{VA_{ijt}}. \quad (3)$$

WWZ decomposition provides a very detailed look at the structures of international production fragmentation. The disadvantage is that one dimension is lost – namely: source industry. It is only feasible to have output of the decomposition according to: the source country, using country and using industry. Consequently, we obtain the information on foreign value-added content in a given domestic industry, but without information from which foreign industry it is sourced. It implies that using WWZ method we can calculate only broad proxy of offshoring (and that is why we compare it with the traditional broad version of offshoring measure defined in eq. 1).

2.2. Trends in offshoring and production sharing: import- *versus* export-based measures

In the first instance we have checked the magnitude of correlation between the two alternative measures of global production sharing defined in eq.1 and eq. 3. The coefficient of correlation between the series of *Off_imp* and *Off_exp* calculated for all countries and sectors is equal to 0.86 which suggests a large dependence between them. It is also shown on Figure 1. Left panel plots the conventional measure (the ratio of imported intermediates with respect to sectoral value added) against the one based on WWZ decomposition (foreign value added with respect to sectoral value added) for all the sample. The relationship between the two is practically linear. Similar pattern emerges when we restrict the sample to OECD countries only (right plot).

Similarly, average values of the two indices calculated for countries are strongly correlated (Figure 2). However, there is very large cross-country variation both in the ratio of imported intermediates to value added (vertical axis) and in the ratio of foreign value added to overall value added (horizontal axis). Table A3 in the Appendix presents cross-country differences between *Off_imp* and *Off_exp* over the period 1995 and 2011. For most of the countries, in the analysed period there was a rise both in FVA and in standard offshoring measure, while the change was especially significant in case of Poland, Japan, Turkey and Germany. However, for some of the countries (e.g. Lithuania, Cyprus, Canada) the indices dropped. For Russia we have an opposite tendency between

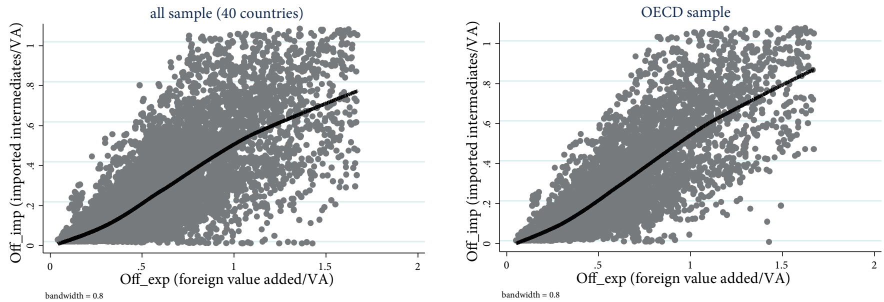

Figure 1. The relationship between import- and export-based measures of offshoring and global production sharing – sector level
Every dot represents country-sector-year observation, the line represents lowess approximation (bandwidth = 0.8). Time period: 1995–2011
Source: Own elaboration based on WWZ methodology and WIOD data

Off_imp and *Off_exp*: a rise in *Off_imp* and a decrease in *Off_exp*. There is also cross – sector discrepancy between *Off_imp* and *Off_exp* (see Table A4 in the Appendix). For all sectors the values of the standard measures are higher than the export-based ones, however for some of the sectors the differences are sig-

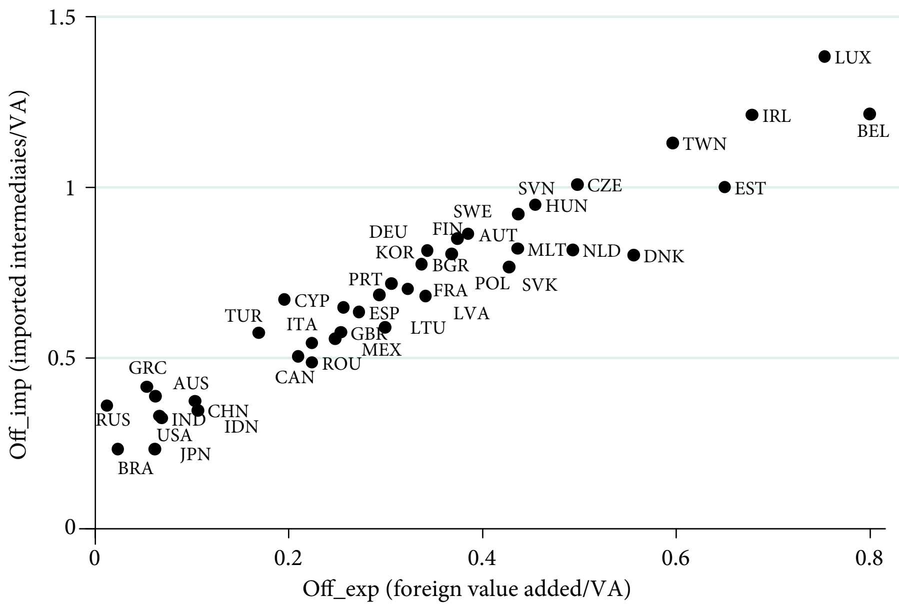

Figure 2. The relationship between import- and export-based measures of offshoring and global production sharing – country level
Average values for countries calculated as weighted averages of the indices obtained for 13 manufacturing sectors, weighted by sector size (in terms of number of persons engaged). Data refer to 2011
Source: Own elaboration based on WWZ methodology and WIOD data

nificant. For instance, in *Food, Beverages And Tobacco* sector the average value of *Off_imp* equals 0.22 while for *Off_exp* only 0.04.

Figure 3 shows the comparison of the evolution of involvement in global production sharing in two European countries: Poland and Germany. They follow similar trend and a rise in foreign value added is observed across time. The ratio of imported intermediates to the value added (*Off_imp*) is typically higher than the one reflecting foreign value added, hence we can expect some differences in estimation results obtained with the two alternative measures.

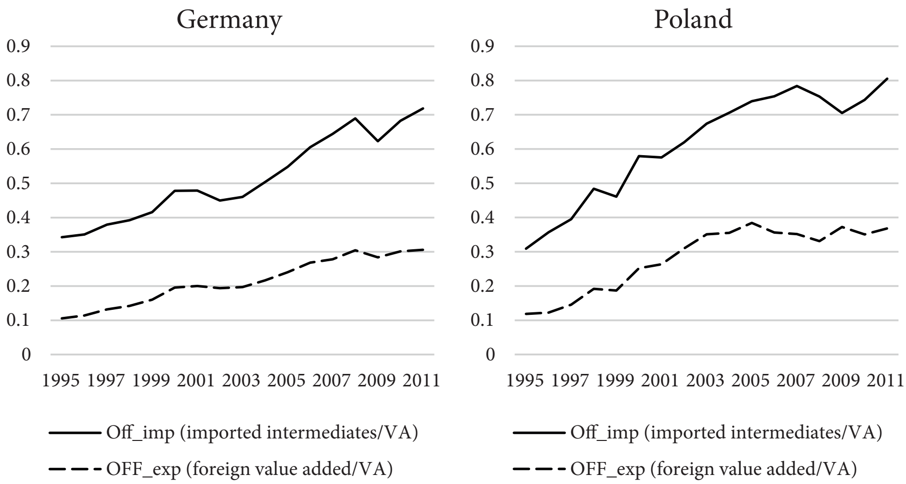

Figure 3. Evolution of import- and export-based measures of offshoring and global production sharing in time (1995–2011) – the example of Germany and Poland

Average values for countries calculated as weighted averages of the indices obtained for 13 manufacturing sectors, weighted by sector size (in terms of in terms of number of persons engaged)

Source: Own elaboration based on WWZ methodology and WIOD data

3. Empirical model and estimation results

The 'Ricardian model' of the labour market [Acemoglu and Autor 2011: 1096–1147] yields the following empirical equation which can be estimated with sector-level data:

$$lnw_{sijt} = \alpha + \beta_1 lnk_{ijt} + \beta_2 lnL_{sijt} + \beta_3 X_{it} + \beta_4 lnOff_{ijt-1} + D_{it} + D_{ij} + D_t + \varepsilon_{sijt}$$
$$\vee s = \{\text{high, medium, low}\}, \quad (4)$$

where:

i – denotes country,
j – sector,
t – refers to time.

Sector level wage, *w*, is measured separately for three categories of workers denoted as *s.* Variable *k* refers to the capital to labour ratio while *L* denotes total number of hours worked per person engaged in a sector (a proxy of sector level skill supply). *X* is set of country specific control variables: *WSC* – level of wage setting coordination (from 1 to 5, where 1 indicates that bargaining predominantly takes place at the local or company level, 5 – bargaining takes place at central or cross-industry level) and *UR* – unemployment rate; *Off* stands for two alternative measures defined in eq. 1 (the traditional measure reflecting the share of imported inputs in value added) and eq. 3 (the measure obtained through gross exports decomposition). To take into account a possible time delay between offshoring indicators and wage adjustment, *Off* term is lagged [the same approach is used in Ebenstein et al. 2014]. Since the variables of our interest are expressed in logarithms we will be able to interpret the estimated parameters as elasticities. In order to pick up any other unmeasurable specific effects (e.g. technological change, business cycle), we include a set of year dummies, as well as country-time dummies and country-industry fixed effects.[11]

As far as the estimation method is concerned, we first estimate equation (3) using standard fixed effects estimator. Table 1 presents the results of a basic estimation, without country specific control variables and performed on the full panel of 40 countries. In subsequent columns we report estimation results for the model where the dependent variable is: average wage paid in the sector (hence all workers are considered: columns 1 and 5) and wage of a specific skill category of workers (columns 2–4 and 6–8). The first four columns refer to the results obtained with traditional offshoring indices while in columns 5–8, the FVA variable is employed.

As expected, wages are positively (and statistically significantly) related to sector's capital to labour ratio (*k*) and negatively related to labour abundance (*L*). An important results appear with respect to our main variable of interest: *Off*. Wages result to be negatively associated with offshoring, both when it is measured in a traditional way (columns 1–4) and when we employ a measure based on FVA. The result holds for all different skill categories of workers: *ceteris paribus*, a 1% rise in offshoring intensity is connected with the wage decrease of 0.06–0.09%. The results are consistent across all skill groups of workers.

In Table 2 we present the estimation results of an augmented specification. Country specific labour market characteristics are controlled for: wage setting

[11] In particular, there is no direct skill-specific productivity data at hand. Following Acemoglu and Autor [2011] we assume that workers productivity is related to the capital intensity of the industry (captured by variable *k*) and, additionally, follows a positive time trend (it shall be captured through the inclusion of a set of dummies in the model).

Table 1. The impact of import and export-based measures of offshoring on wages – FE estimation, basic model. Dependent variable: lnw_{sijt}

Workers	*Off_imp* [eq. 1]				*Off_exp* [eq. 3]			
	all	low-skilled	medium-skilled	high-skilled	all	low-skilled	medium-skilled	high-skilled
lnk_{ijt}	0.261***	0.398***	0.311***	0.314***	0.262***	0.399***	0.313***	0.317***
	[0.028]	[0.044]	[0.038]	[0.038]	[0.028]	[0.043]	[0.038]	[0.038]
lnL_{sijt}	–0.153***	–0.072**	–0.174***	–0.188***	–0.152***	–0.068**	–0.170***	–0.181***
	[0.038]	[0.034]	[0.032]	[0.034]	[0.037]	[0.034]	[0.032]	[0.034]
lnOff_{ijt-1}	–0.058***	–0.086***	–0.079***	–0.060**	–0.069***	–0.075***	–0.078***	–0.077***
	[0.020]	[0.023]	[0.022]	[0.024]	[0.014]	[0.015]	[0.015]	[0.016]
R^2	0.451	0.403	0.394	0.329	0.459	0.409	0.404	0.34
N	7960	7237	7247	7228	7935	7212	7222	7203

Constant included – not reported. Robust standard errors in parentheses, clustered at the country-industry level. Statistically significant at ***1, ** 5, * 10 percent level. In all specifications year dummies, country-industry and country-year fixed effects are included.

Source: Own calculations with data from WIOD.

Table 2. The impact of import and export-based measures of offshoring on wages – FE estimation, model with additional variables. Dependent variable: lnw_{sijt}

Workers	*Off_imp* [eq. 1]				*Off_exp* [eq. 3]			
	all	low-skilled	medium-skilled	high-skilled	all	low-skilled	medium-skilled	high-skilled
lnk_{ijt}	0.247***	0.384***	0.301***	0.290***	0.247***	0.383***	0.300***	0.291***
	[0.025]	[0.041]	[0.035]	[0.033]	[0.025]	[0.041]	[0.034]	[0.033]
lnL_{sijt}	–0.129***	–0.059**	–0.129***	–0.172***	–0.129***	–0.059**	–0.129***	–0.167***
	[0.031]	[0.030]	[0.028]	[0.029]	[0.031]	[0.029]	[0.027]	[0.029]
lnOff_{ijt-1}	–0.050**	–0.074***	–0.063***	–0.040*	–0.052***	–0.056***	–0.056***	–0.052***
	[0.020]	[0.022]	[0.021]	[0.024]	[0.013]	[0.015]	[0.014]	[0.016]
WSC_{it}	–0.011**	0.008	0.016***	–0.003	–0.010*	0.009	0.017***	–0.002
	[0.006]	[0.007]	[0.005]	[0.007]	[0.006]	[0.007]	[0.005]	[0.007]
UR_{it}	–0.011***	–0.013***	–0.012***	–0.007***	–0.010***	–0.012***	–0.012***	–0.007***
	[0.001]	[0.002]	[0.002]	[0.002]	[0.001]	[0.002]	[0.002]	[0.002]
R^2	0.51	0.455	0.458	0.363	0.515	0.457	0.462	0.368
N	7375	6652	6662	6643	7350	6627	6637	6618

Constant included – not reported. Robust standard errors in parentheses, clustered at the country-industry level. Statistically significant at ***1, ** 5, * 10 percent level. In all specifications year dummies, country-industry and country-year fixed effects are included.

Source: Own calculations with data from WIOD.

coordination (*WSC*) and unemployment rate (*UR*) which can have an impact on the speed of wage adjustment in the presence of offshoring. For example, if wages are rigid then the offshoring effect should rather materialize through employment loss than through wages. This time due to limited data availability the sample is restricted to 39 countries (there is no information on wage setting mechanism for Taiwan).

The previous results are confirmed, even though in an augmented specification the impact of production sharing on wages is lower than the one reported in Table 1. Additionally, wages are negatively correlated with unemployment rate: the higher the unemployment, the lower the wages. Interestingly, when the wage bargaining takes place at the central (state) level, it is beneficial for the medium-skilled workers (positive parameter in front of *WSC* variable), but not necessarily for the whole group of workers (negative parameter in columns 1 and 5). We

Table 3. The impact of import and export-based measures of offshoring on wages – IV estimation, basic model. Dependent variable: $\ln w_{sijt}$

Workers	*Off_imp* [eq. 1]				*Off_exp* [eq. 3]			
	all	low-skilled	medium-skilled	high-skilled	all	low-skilled	medium-skilled	high-skilled
$\ln k_{ijt}$	0.262***	0.369***	0.311***	0.307***	0.268***	0.424***	0.337***	0.349***
	[0.030]	[0.052]	[0.043]	[0.041]	[0.034]	[0.047]	[0.044]	[0.047]
$\ln L_{sijt}$	−0.189***	−0.129***	−0.175***	−0.201***	−0.109**	−0.002	−0.100**	−0.102**
	[0.041]	[0.045]	[0.036]	[0.036]	[0.046]	[0.041]	[0.042]	[0.048]
$\ln Off_{ijt-1}$	0.337	0.439	−0.071	0.123	−0.530***	−0.485***	−0.543***	−0.613***
	[0.267]	[0.277]	[0.252]	[0.278]	[0.065]	[0.063]	[0.070]	[0.071]
N	7960	7237	7247	7228	7932	7210	7220	7201
Under-ident. test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weak ident. test	10.1	11.7	10.6	11.8	82.4	80.5	74.9	84.9

Robust standard errors in parentheses, clustered at the country-industry level. Statistically significant at ***1, ** 5, * 10 percent level. In all specifications, year dummies, country-industry and country-year fixed effects included. Estimates obtained with the broad offshoring measure. Offshoring treated as endogenous variables and instrumented on the basis of the gravity equation as explained in the main text. The figures reported for the under-identification test are the p-values and refer to the Kleibergen-Paap rk LM test statistic, where a rejection of the null indicates that the instruments are not under-identified. The weak identification test refers to the Kleibergen-Paap Wald rk F statistic test for the presence of weak instruments. As a "rule of thumb" the statistic should be at least 10 for weak identification not to be considered a problem [Staiger and Stock 1997].

Source: Own calculations with data from WIOD.

can so far conclude that in fixed effects setting the choice of a particular offshoring index does not alter significantly the results concerning its impact on wages.

Endogeneity is one of the potential problems in the model which has not been taken into account so far. First of all, we perform the endogeneity tests for suspicious variables, namely: labour (*L*) and offshoring (*Off*). The direction of the relationship between those variables and wages can be ambiguous, for instance wage level can impact the employment decisions, and in turn offshoring intensity can be determined by wages (through offshoring firms seek cost savings so they compare wages of paid in domestic sectors with respect to the foreign ones). The results of the endogeneity tests are presented in Table A5 in Appendix and the hypothesis of exogeneity of offshoring indices is strongly rejected.

To solve this problem we built an instrument based on gravity equation. We employ gravity type regression with either intermediate imports or foreign value added exports as a dependent variable (bilateral specification for 40 countries and separately for 13 manufacturing industries) and a set of regressors: reporter's and partner's value added of a given sector, distance, dummy for common

Table 4. The impact of import- and export-based measures of offshoring on wages – IV estimation, model with additional variables. Dependent variable: lnw_{sijt}

Workers	*Off_imp* [eq. 1]				*Off_exp* [eq. 3]			
	all	low-skilled	medium-skilled	high-skilled	all	low-skilled	medium-skilled	high-skilled
lnk_{ijt}	0.244***	0.307***	0.262***	0.252***	0.248***	0.402***	0.312***	0.322***
	[0.036]	[0.068]	[0.050]	[0.047]	[0.028]	[0.042]	[0.037]	[0.040]
lnL_{sijt}	–0.209***	–0.192**	–0.188***	–0.225***	–0.101***	–0.008	–0.091***	–0.097**
	[0.055]	[0.079]	[0.051]	[0.047]	[0.038]	[0.036]	[0.035]	[0.043]
lnOff_{ijt-1}	0.768	1.015	0.528	0.594	–0.419***	–0.389***	–0.404***	–0.525***
	[0.701]	[0.955]	[0.401]	[0.435]	[0.064]	[0.071]	[0.071]	[0.080]
WSC_{it}	–0.01	0.023*	0.024***	0.003	0.001	0.011*	0.020***	0.003
	[0.009]	[0.014]	[0.009]	[0.010]	[0.007]	[0.007]	[0.006]	[0.007]
UR_{it}	–0.011***	–0.020***	–0.016***	–0.011***	–0.005***	–0.006***	–0.005**	0.002
	[0.002]	[0.005]	[0.003]	[0.003]	[0.002]	[0.002]	[0.002]	[0.003]
N	7375	6652	6662	6643	7347	6625	6635	6616
Under-ident. test	0.01	0.02	0.03	0.02	0.00	0.00	0.00	0.00
Weak ident. test	6.6	5.4	4.9	5.3	56.5	52.0	45.6	55.7

Notes as under Table 3.

Source: own calculations with data from WIOD.

border, common official language, common currency, former colonial relationship and membership in a common regional trade agreement. This approach is based on Giovanni and Levchenko [2009] method.

In Table 3 and in Table 4 we present the results when the offshoring indices (whether the traditional or the FVA) are instrumented with the use of gravity equation. In Table 4 the equation is enriched with the additional control variables. There is one main difference between IV results and previously discussed FE estimates. Now the offshoring measured in a traditional way (*Off_imp*) loses its statistical significance. On the contrary, the *Off_exp* variable based on FVA remains statistically significant also in the IV setting and suggests negative relationship between foreign value added content in exports and wages.

Conclusions

In the present study we have shown different ways of quantifying offshoring with the use of industry level data. We have demonstrated the application of two measures. The traditional one isobtained using information on imports (in particular, imports of intermediate inputs).The second one belongs to a new class of indices based on the decomposition of gross exports and value added counting. The analysed sample encompasses 40 countries and takes into account wages of different skill categories of workers employed in 12 manufacturing sectors over the period 1995–2009 (offshoring indices are calculated till 2011). As far as the magnitude of the indices is considered, the new measures are lower than the traditional ones; however the correlation between them is high. There is significant cross-country and cross-sector variability in this context.

In the empirical part of the study, we have confronted the results of wage equation estimation performed with the use of ‘import- and export-based measures of cross border production sharing. The wage regression is conducted separately for overall wages and three distinct workers categories (low, medium and high-skilled). In fixed effects setting, statistically significant results on offshoring-wage relationship are obtained both when offshoring is measured as the ratio of imported inputs in sectoral value added and when it is measured as the ratio of foreign value-added. So in this case the way of quantifying offshoring does not matter for the conclusions drawn: one could conclude that major involvement in vertical specialization affects negatively wages of the domestic workers. However, when we change the estimation method, accounting for endogeneity issues, the results differ according to the particular measure of production sharing used. The negative association between offshoring and wages is sustained only in case of the measures based on FVA. We can thus argue that the usage of the two different methods of offshoring quantification can affect the conclusions drawn in estimations taking into account endogeneity in offshoring-wages relationship.

Appendix

Table A1. List of countries in the sample

Country code	Country name	Country code	Country name
AUS	Australia	IRL	Ireland
AUT	Austria	ITA	Italy
BEL	Belgium	JPN	Japan
BGR	Bulgaria	KOR	Korea
BRA	Brazil	LTU	Lithuania
CAN	Canada	LUX	Luxembourg
CHN	China	LVA	Latvia
CYP	Cyprus	MEX	Mexico
CZE	Czech Republic	MLT	Malta
DEU	Germany	NLD	Netherlands
DNK	Denmark	POL	Poland
ESP	Spain	PRT	Portugal
EST	Estonia	ROM	Romania
FIN	Finland	RUS	Russia
FRA	France	SVK	Slovak Republic
GBR	United Kingdom	SVN	Slovenia
GRC	Greece	SWE	Sweden
HUN	Hungary	TUR	Turkey
IDN	India	TWN	Taiwan
IND	Indonesia	USA	United States of America

Table A2. List of industries

Industry code	Description
15t16	Food, Beverages And Tobacco
17t18	Textiles And Textile Products
19	Leather, Leather And Footwear
20	Wood and Products of Wood and Cork
21t22	Pulp, Paper, Printing And Publishing
24	Chemicals and Chemical Products
25	Rubber And Plastics
26	Other Non-Metallic Mineral Products
27t28	Basic Metals And Fabricated Metal
29	Machinery not elsewhere classified
30t33	Electrical And Optical Equipment
34t35	Transport Equipment
36t37	Manufacturing not elsewhere classified; Recycling

Table A3. Import and export-based measures of offshoring across countries: 1995 and 20011

Country	1995		2011		Total change in %	
	Off_imp	*Off_exp*	*Off_imp*	*Off_exp*	*Off_imp*	*Off_exp*
AUS	0.27	0.04	0.39	0.06	44.5	38.9
AUT	0.49	0.20	0.86	0.39	74.5	93.5
BEL	1.08	0.63	1.22	0.80	12.7	27.0
BGR	0.57	0.21	0.78	0.34	36.2	63.9
BRA	0.13	0.01	0.23	0.02	74.3	67.4
CAN	0.56	0.25	0.50	0.21	–9.7	–15.5
CHN	0.25	0.08	0.35	0.11	38.5	28.7
CYP	0.79	0.33	0.67	0.20	–15.1	–40.8
CZE	0.73	0.33	1.01	0.50	38.2	48.9
DEU	0.34	0.11	0.72	0.31	109.6	189.4

DNK	0.54	0.32	0.80	0.56	49.0	75.6
ESP	0.41	0.12	0.63	0.27	56.1	125.0
EST	0.75	0.49	1.00	0.65	33.3	31.4
FIN	0.45	0.20	0.82	0.34	81.3	69.2
FRA	0.45	0.16	0.70	0.32	55.7	107.2
GBR	0.42	0.15	0.58	0.25	38.0	70.0
GRC	0.44	0.06	0.42	0.05	–5.2	–7.4
HUN	0.77	0.27	0.95	0.45	23.7	66.5
IDN	0.24	0.07	0.37	0.10	57.4	48.3
IND	0.26	0.05	0.32	0.07	24.9	37.8
IRL	0.86	0.49	1.21	0.68	40.6	39.7
ITA	0.38	0.14	0.54	0.22	44.6	65.2
JPN	0.10	0.01	0.23	0.06	145.8	404.3
KOR	0.49	0.16	0.69	0.29	41.0	78.7
LTU	0.72	0.38	0.59	0.30	–18.4	–20.9
LUX	0.93	0.65	1.38	0.75	49.5	16.1
LVA	0.47	0.22	0.68	0.34	46.5	53.6
MEX	0.45	0.16	0.56	0.25	23.1	52.9
MLT	0.81	0.29	0.82	0.44	1.2	49.9
NLD	0.81	0.51	0.82	0.49	1.1	–2.6
POL	0.31	0.12	0.81	0.37	160.7	210.9
PRT	0.59	0.26	0.65	0.26	9.0	–1.1
ROU	0.39	0.16	0.49	0.22	26.2	39.1
RUS	0.26	0.04	0.36	0.01	38.9	–68.6
SVK	0.65	0.39	0.77	0.43	17.6	10.7
SVN	0.72	0.38	0.92	0.44	27.3	14.3
SWE	0.54	0.25	0.85	0.37	57.7	47.9
TUR	0.24	0.06	0.57	0.17	143.7	170.8
TWN	0.88	0.48	1.13	0.60	28.1	23.0
USA	0.22	0.03	0.33	0.07	53.2	129.3

Average values for countries calculated as weighted averages of the indices obtained for 13 manufacturing sectors, weighted by sector size (in terms of persons engaged).

Source: Own elaboration based on WWZ methodology and WIOD data.

Table A4. The cross-industry differences in import and export-based measures of offshoring

Industry code	*Off_imp*	*Off_exp*
15t16	0.22	0.04
17t18	0.30	0.15
19	0.31	0.21
20	0.22	0.05
21t22	0.26	0.03
24	0.43	0.10
25	0.43	0.11
26	0.20	0.03
27t28	0.46	0.08
29	0.35	0.13
30t33	0.66	0.30
34t35	0.53	0.18
36t37	0.29	0.20

Average values for sectors over 1995 and 2011 calculated as weighted averages of the indices obtained for 40 countries, weighted by country's sector size (in terms of persons engaged).

Source: Own elaboration based on WWZ methodology and WIOD data.

Table A5. Endogeneity tests

Endogeneity test for the mean wages			
	lnL_{ijt}	lnOff_imp_{ijt}	lnOff_exp_{ijt}
Test stat [χ^2 (1)]	2.494	0.863	460.20
p-value	0.1143	0.3530	0.0000
Endogeneity test for the low-skilled wages			
Test stat [χ^2 (1)]	1.196	8.536	319.00
p-value	0.2741	0.0035	0.0000
Endogeneity test for the medium-skilled wages			
Test stat [χ^2 (1)]	0.434	12.367	398.05
p-value	0.5099	0.0004	0.0000
Endogeneity test for the high-skilled wages			
Test stat [χ^2 (1)]	2.452	6.043	5503.89
p-value	0.1173	0.0140	0.0000

GMM distance test based on one-year lag of: lnL_{ijt}, and gravity instrument of: lnOff_imp_{ijt} and lnOff_exp_{ijt}. H0: the regressor can be treated as exogenous; computed with xtivreg2 in STATA.

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