Llop *Journal of Economic Structures* (2022) 11:25
https://doi.org/10.1186/s40008-022-00285-5

Journal of Economic Structures

RESEARCH Open Access

Quantifying the employment impacts of gross exports: a global accounting perspective

Maria Llop*

*Correspondence:
maria.llop@urv.cat

ECO-SOS Research Centre, Departament d'Economia, Universitat Rovira i Virgili, Avinguda Universitat 1, 43204 Reus, Spain

Abstract

This article presents a method for quantifying the (domestic) employment consequences directly attributed to gross exports by taking into account the complex and global nature of production chains. Using a multi-country input–output (IO) structure of world production, the method derives measurements for the number of jobs and amount of labour income supported by a country's export-related production. By quantifying how much domestic employment is determined by a country's export activity, it offers a complementary (labour-focused) view on the more common (value-added focused) analyses for evaluating the economic impact of trade. This approach highlights the importance of exports in creating jobs and labour income, especially in the European Union and China. In contrast, gross exports in the United States show a (comparatively) weak influence in supporting US employment.

Keywords: International trade, Employment, Labour income, Multi-regional input–output model

1 Introduction

Globalization has substantially transformed world production in that manufacturing is now internationally divided into different stages created by different firms in different countries around the world. Since several economies take part in multiple steps before the final goods are completed, production has become a complex system in which firms are involved in highly specialized phases rather than the entire process.[1] Accordingly, product fragmentation has modified trade operations, which have evolved towards complicated flows of goods transiting between many interconnected countries.

The disintegration of production makes it difficult to clearly establish the positions of countries in relation to aspects, such as the efficiency of local production, the prices of domestic goods relative to those of foreign ones, and the strength or vulnerability of external demand. This presents a challenge for identifying the importance of trade to

[1] See, for instance, Feenstra (1998), Hummels et al. (2001), Yi (2003), Los et al. (2015a), and Timmer et al. (2019) for product fragmentation studies.

domestic economies, especially if the part played by trade in boosting local incomes and local welfare is to be evaluated.

One method of quantifying the consequences of trade for individual economies that has recently received intensive research effort is to calculate the (domestic) value added embodied in exports. In particular, Johnson and Noguera (2012) proposed an accounting measurement for evaluating the value added inserted in trade operations. Koopman et al. (2014) used the inter-country relationships of the input–output (IO) model to identify various value-added components within gross exports. Their framework was later extended by Los et al. (2016), who introduced the input–output hypothetical extraction method (HEM) to clarify the measurements proposed by Koopman et al. (2014). In parallel, Borin and Mancini (2017) further analysed the method of Koopman et al. (2014) to consistently define bilateral trade flows. Los and Timmer (2018), for their part, proposed an extension of the HEM to obtain the value added of gross exports both bilaterally and globally. Wang et al. (2018) distinguished the inter-sectoral backward and forward linkages in the measurement of the value added of exports and generalized the accounting method to sectors of production and pairs of countries. Arto et al. (2019) proposed an evaluation of the value added of exports measured at the border by including all countries and industries that take part in the value-added flows. To further clarify double counting in the measurement of trade flows, Mirodout and Ye (2020) moved the accounting to the sales of foreign affiliates to determine their impact on host economies. More recently, Mirodout and Ye (2021) proposed a framework that can distinguish domestic and foreign value added measured globally, bilaterally, and individually.

The present paper falls within this line of literature but, rather than focusing on the (production-related) value added of exports, it evaluates the (labour-related) impacts on employment and factor income. The extent to which gross exports create jobs and expand income domestically, thus helping boost individuals' welfare, is of particular interest for national authorities. Bearing this idea in mind, this paper can be considered complementary to existing (value-added focused) studies that quantify the importance of trade on domestic economies. At the country level, the proposed method quantifies the additional number of workers and the amount of labour income that should be attributed to export activity. At the global (multi-country) level, it illustrates the distributional mechanisms that operate across countries, especially those related to labour issues.

There is a rich vein of literature that analyses the relationship between international trade and employment, both empirically and theoretically, and focuses on specific (partial) issues, such as the relationship between income distribution and wages,[2] the implications of trade for employment,[3] the wage and unemployment gaps between skilled and unskilled labour caused by trade,[4] the impacts of trade liberalization on relative prices and on employment,[5] and the labour market implications of international fragmentation.[6]

[2] See, for instance, Krugman (2010) and Egger and Etzel (2012) for theoretical approaches.

[3] Autor et al. (2013; 2015), Van Ha and Tran (2017), and Shen and Silva (2018), among others, showed empirical analyses.

[4] For example, Wood (1995, 1998), Feenstra (1998), and Di Comite et al. (2017) analysed these issues.

[5] See, for example, Feenstra and Hanson (2003) and Egger et al. (2013).

[6] For instance, Egger and Kreickemeier (2008).

Additionally, numerous papers use a macroeconomic perspective to evaluate the contribution of external markets to creating income, employment, and economic activity within domestic economies. In this line of research, the multi-regional input–output model has demonstrated great explanatory capacity for capturing the interdependence and connections inherent to international trade. In particular, Timmer et al. (2013) constructed a multi-regional IO model of the global value chains of sectors to determine the structure of employment in EU countries. Los et al. (2015b) analysed the impact of foreign demand on employment creation in China by using global input–output methodology. With a similar procedure, Chen et al. (2017) calculated the consequences of Brexit for European Union (EU) regions by quantifying GDP reductions and negative (monetary) impacts on labour income. For EU countries, Arto et al. (2018) featured a series of indicators to detail the employment impacts of international trade by focusing on individual European Union member states, their trading partners, industries, skills, age, and gender. Similarly, Arto et al. (2020) reported indicators to show how final demand in each country of the European Union contributed to EU employment.

The present analysis examines the main countries in the world to calculate the macroeconomic impacts of trade on employment. The method employed provides a complementary (global) view to explain the significance of export activity in supporting employment around the world. In particular, it focuses on an accounting perspective based on an inter-country input–output framework to quantify the number of jobs and amount of labour income directly attributed to exports. By considering a portrait of world production, the method fully reflects the global value chains and worldwide propagation mechanisms triggered by trade. Since the proposal includes IO inter-sectoral and inter-country relationships, it illustrates how exports increase sectoral production and how this new production is converted into jobs, thus influencing the domestic demand for labour. It also quantifies the labour income created by a country's export activity. The method has excellent explanatory capacity in terms of its reliability in capturing the multi-lateral channels of the fragmented value chains, and can be applied empirically using available global input–output databases.

The rest of the paper is organized as follows. Section "A global model of employment accounting" defines a global accounting mechanism through which various indicators are derived to measure the number of jobs and the amount of labour income attributed to export activity. Section "Database" describes the database and Section "Employment impacts of gross exports" shows the empirical results. Finally, Section "Conclusions" draws several conclusions.

2 A global model of employment accounting

Let us divide the world into seven countries or regions (m), namely, the European Union (e), China (c), the United States (u), Japan (j), Australia (a), Brazil (b), and the Rest of the World (r): $m = e, c, u, j, a, b, r$. Each region produces $i = 1, \cdots, 56$ goods, which can be used either as intermediate inputs or as final products. Intermediate and final goods are either domestically consumed or exported to each other region or country.

The input–output model characterizing the world production system can be represented as follows:[7]

$$\begin{bmatrix} x_e \\ x_c \\ x_u \\ x_j \\ x_a \\ x_b \\ x_r \end{bmatrix} = \begin{bmatrix} a_{ee} & a_{ec} & a_{eu} & a_{ej} & a_{ea} & a_{eb} & a_{er} \\ a_{ce} & a_{cc} & a_{cu} & a_{cj} & a_{ca} & a_{cb} & a_{cr} \\ a_{ue} & a_{uc} & a_{uu} & a_{uj} & a_{ua} & a_{ub} & a_{ur} \\ a_{je} & a_{jc} & a_{ju} & a_{jj} & a_{ja} & a_{jb} & a_{jr} \\ a_{ae} & a_{ac} & a_{au} & a_{aj} & a_{aa} & a_{ab} & a_{ar} \\ a_{be} & a_{bc} & a_{bu} & a_{bj} & a_{ba} & a_{bb} & a_{br} \\ a_{re} & a_{rc} & a_{ru} & a_{rj} & a_{ra} & a_{rb} & a_{rr} \end{bmatrix} \begin{bmatrix} x_e \\ x_c \\ x_u \\ x_j \\ x_a \\ x_b \\ x_r \end{bmatrix} + \begin{bmatrix} Y_{ee} & Y_{ec} & Y_{eu} & Y_{ej} & Y_{ea} & Y_{eb} & Y_{er} \\ Y_{ce} & Y_{cc} & Y_{cu} & Y_{cj} & Y_{ca} & Y_{cb} & Y_{cr} \\ Y_{ue} & Y_{uc} & Y_{uu} & Y_{uj} & Y_{ua} & Y_{ub} & Y_{ur} \\ Y_{je} & Y_{jc} & Y_{ju} & Y_{jj} & Y_{ja} & Y_{jb} & Y_{jr} \\ Y_{ae} & Y_{ac} & Y_{au} & Y_{aj} & Y_{aa} & Y_{ab} & Y_{ar} \\ Y_{be} & Y_{bc} & Y_{bu} & Y_{bj} & Y_{ba} & Y_{bb} & Y_{br} \\ Y_{re} & Y_{rc} & Y_{ru} & Y_{rj} & Y_{ra} & Y_{rb} & Y_{rr} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, \tag{1}$$

or alternatively:

$$\begin{bmatrix} x_e \\ x_c \\ x_u \\ x_j \\ x_a \\ x_b \\ x_r \end{bmatrix} = \begin{bmatrix} I - a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1} \begin{bmatrix} Y_{ee} & Y_{ec} & Y_{eu} & Y_{ej} & Y_{ea} & Y_{eb} & Y_{er} \\ Y_{ce} & Y_{cc} & Y_{cu} & Y_{cj} & Y_{ca} & Y_{cb} & Y_{cr} \\ Y_{ue} & Y_{uc} & Y_{uu} & Y_{uj} & Y_{ua} & Y_{ub} & Y_{ur} \\ Y_{je} & Y_{jc} & Y_{ju} & Y_{jj} & Y_{ja} & Y_{jb} & Y_{jr} \\ Y_{ae} & Y_{ac} & Y_{au} & Y_{aj} & Y_{aa} & Y_{ab} & Y_{ar} \\ Y_{be} & Y_{bc} & Y_{bu} & Y_{bj} & Y_{ba} & Y_{bb} & Y_{br} \\ Y_{re} & Y_{rc} & Y_{ru} & Y_{rj} & Y_{ra} & Y_{rb} & Y_{rr} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, \tag{2}$$

where the elements x_m contain the 56×1 sectoral production in each country, so the resulting vector on the left-hand side of Eq. (2) has a dimension 392×1; the a_{mm} are 7×7 blocks of input–output inter-country coefficients, so the dimension of the inverse matrix in (2) is 392×392; Y_{mm} are the 56×1 elements of the final demand in each region, resulting in a 392×7 matrix. Finally, the right-hand side of Eq. (2) contains a 7×1 vector of unitary elements.

It should be noted that the model described in expression (2) reflects a global system of world production that defines sectoral production in function of the bilateral (intermediate and final) transactions between all regions.

From the model above, physical employment (E_m) in each region is derived from:

[7] See Miller and Blair (2009) for a description of the multi-country input–output model.

$$\begin{bmatrix} E_e \\ E_c \\ E_u \\ E_j \\ E_a \\ E_b \\ E_r \end{bmatrix} = \begin{bmatrix} p_e & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & p_c & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & p_u & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & p_j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & p_a & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & p_b & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & p_r \end{bmatrix}$$
$$\begin{bmatrix} I-a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I-a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I-a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I-a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I-a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I-a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I-a_{rr} \end{bmatrix}^{-1} \quad (3)$$
$$\begin{bmatrix} Y_{ee} & Y_{ec} & Y_{eu} & Y_{ej} & Y_{ea} & Y_{eb} & Y_{er} \\ Y_{ce} & Y_{cc} & Y_{cu} & Y_{cj} & Y_{ca} & Y_{cb} & Y_{cr} \\ Y_{ue} & Y_{uc} & Y_{uu} & Y_{uj} & Y_{ua} & Y_{ub} & Y_{ur} \\ Y_{je} & Y_{jc} & Y_{ju} & Y_{jj} & Y_{ja} & Y_{jb} & Y_{jr} \\ Y_{ae} & Y_{ac} & Y_{au} & Y_{aj} & Y_{aa} & Y_{ab} & Y_{ar} \\ Y_{be} & Y_{bc} & Y_{bu} & Y_{bj} & Y_{ba} & Y_{bb} & Y_{br} \\ Y_{re} & Y_{rc} & Y_{ru} & Y_{rj} & Y_{ra} & Y_{rb} & Y_{rr} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix},$$

where p_m are 56×56 diagonal matrices containing the ratios of the (physical) number of employees in each sector by sectoral gross output in the main diagonal and zeros elsewhere, resulting in a 392×392 matrix of employment coefficients.

Alternatively, the model can also evaluate the labour income linked to gross exports. By transforming the multi-country structure, employment incomes (L_m) are obtained from:

$$\begin{bmatrix} L_e \\ L_c \\ L_u \\ L_j \\ L_a \\ L_b \\ L_r \end{bmatrix} = \begin{bmatrix} w_e & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & w_c & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & w_u & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & w_j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & w_a & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & w_b & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & w_r \end{bmatrix}$$
$$\begin{bmatrix} I-a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I-a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I-a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I-a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I-a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I-a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I-a_{rr} \end{bmatrix}^{-1} \quad (4)$$
$$\begin{bmatrix} Y_{ee} & Y_{ec} & Y_{eu} & Y_{ej} & Y_{ea} & Y_{eb} & Y_{er} \\ Y_{ce} & Y_{cc} & Y_{cu} & Y_{cj} & Y_{ca} & Y_{cb} & Y_{cr} \\ Y_{ue} & Y_{uc} & Y_{uu} & Y_{uj} & Y_{ua} & Y_{ub} & Y_{ur} \\ Y_{je} & Y_{jc} & Y_{ju} & Y_{jj} & Y_{ja} & Y_{jb} & Y_{jr} \\ Y_{ae} & Y_{ac} & Y_{au} & Y_{aj} & Y_{aa} & Y_{ab} & Y_{ar} \\ Y_{be} & Y_{bc} & Y_{bu} & Y_{bj} & Y_{ba} & Y_{bb} & Y_{br} \\ Y_{re} & Y_{rc} & Y_{ru} & Y_{rj} & Y_{ra} & Y_{rb} & Y_{rr} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix},$$

where w_m are 56×56 diagonal matrices containing the ratios between sectoral (monetary) labour compensation and sectoral gross output in the main diagonal and zeros elsewhere for the m regions, thus configuring a 392×392 matrix of labour income coefficients.

Los et al. (2016) and Los and Timmer (2018) proposed the use of the "hypothetical extraction method"[8] to quantify how much domestic value added is contained in a country's exports. This method defines hypothetical situations that nullify certain elements of interest in the input–output model. The idea is to evaluate how the model changes when a certain part is removed from the system. Comparing the real values for the variable of interest (e.g., sectoral output, value added, factorial income, etc.) with those corresponding to an extreme (and unreal) case in which some selected elements do not exist is a way of quantifying how the removed element contributes to the system. According to this idea, the impacts on labour due to export activity can be determined by removing all the exports from the model and comparing the resulting values of expressions (4) and (6). In particular, the difference between real employment (E) and hypothetical employment if the economy does not export abroad (neither intermediate nor final goods) (E^*) can be interpreted as the *employment attributed to direct exports* (EXD). For instance, the number of jobs due to gross exports in the European Union (EXD_e) can be obtained by modelling a hypothetical situation that extracts all exports (intermediate and final) from e to all the other regions. The new (fictitious) number of jobs (E_e^*) is then given by

$$E_e^* = \begin{bmatrix} p_e & 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} I - a_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1}$$
$$\begin{bmatrix} Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ce} & Y_{cc} & Y_{cu} & Y_{cj} & Y_{ca} & Y_{cb} & Y_{cr} \\ Y_{ue} & Y_{uc} & Y_{uu} & Y_{uj} & Y_{ua} & Y_{ub} & Y_{ur} \\ Y_{je} & Y_{jc} & Y_{ju} & Y_{jj} & Y_{ja} & Y_{jb} & Y_{jr} \\ Y_{ae} & Y_{ac} & Y_{au} & Y_{aj} & Y_{aa} & Y_{ab} & Y_{ar} \\ Y_{be} & Y_{bc} & Y_{bu} & Y_{bj} & Y_{ba} & Y_{bb} & Y_{br} \\ Y_{re} & Y_{rc} & Y_{ru} & Y_{rj} & Y_{ra} & Y_{rb} & Y_{rr} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}. \tag{5}$$

Using these values, the employment attributed to gross exports in the EU can be obtained as the difference between the actual values (E_e) and the hypothetical values:

$$EXD_e = E_e - E_e{}^*, \tag{6}$$

and a similar procedure can be applied for the other regions. To obtain a relative measurement, the (absolute) employment quantification in expression (6) can be transformed into a proportion of total employment in the corresponding region as follows:

[8] See Paelink et al. (1965), Strassert (1968), and Schultz (1977) for their pioneering contributions to the hypothetical extraction method. Dietzenbacher and Lahr (2013) generalized the extraction techniques and suggested a way to use the method. More recently, Dietzenbacher et al. (2019) proposed an adaptation of the extraction method for use with global systems.

$$\frac{EXD_m}{E_m} = \frac{E_m - E_m{}^*}{E_m}.$$

It should be noted that the employment from exports defined in expression (6) is quantitatively limited to total employment, since the number of jobs created by gross exports inside the economy cannot be greater than the observed (real) value. Moreover, the larger (lower) the value EXD_m, the higher (lower) the effect of trade activity on domestic labour demand in region m.

Similarly, the *labour income attributed to direct exports* (LXD) is obtained as the difference between the real labour income (L) and the hypothetical labour income when all exports (L^*) are cancelled out. For the European Union, this evaluation would be

$$L_e^* = \begin{bmatrix} w_e & 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} I - a_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1}$$
$$\begin{bmatrix} Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ce} & Y_{cc} & Y_{cu} & Y_{cj} & Y_{ca} & Y_{cb} & Y_{cr} \\ Y_{ue} & Y_{uc} & Y_{uu} & Y_{uj} & Y_{ua} & Y_{ub} & Y_{ur} \\ Y_{je} & Y_{jc} & Y_{ju} & Y_{jj} & Y_{ja} & Y_{jb} & Y_{jr} \\ Y_{ae} & Y_{ac} & Y_{au} & Y_{aj} & Y_{aa} & Y_{ab} & Y_{ar} \\ Y_{be} & Y_{bc} & Y_{bu} & Y_{bj} & Y_{ba} & Y_{bb} & Y_{br} \\ Y_{re} & Y_{rc} & Y_{ru} & Y_{rj} & Y_{ra} & Y_{rb} & Y_{rr} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}. \tag{7}$$

The difference between the actual value and the hypothetical value for labour income is equal to the labour income from export activity in the EU (LX_e):

$$LXD_e = L_e - L_e{}^*, \tag{8}$$

and the calculations for the other regions would be parallel. Finally, the (absolute) labour income in m can be easily transformed into a proportion of the observed value as follows:

$$\frac{LXD_m}{L_m} = \frac{L_m - L_m{}^*}{L_m}.$$

With regard to labour income from exports, the larger (lower) the value LXD, the higher (lower) the influence of exports on labour income in region m. This value is quantitatively limited by total labour income, since for each region m the labour compensation supported by exports cannot exceed the observed value.

The EXD and LXD presented above completely cancel out the exports of countries (i.e., intermediate exports and final exports), thus providing an upper limit for the employment impact of the exporting activity. According to Los and Timmer (2018), who provide various measures of the GDP contained in exports, other economic dependencies can be defined by eliminating certain parts of the input–output relationships. In particular, *employment attributed to foreign final production* (EXP) and *labour income attributed to foreign final production* (LXP) are obtained by extracting

from a country's final demand the demand for output produced in the other countries. In the particular case of the European Union, the (fictitious) number of jobs (E_e^{**}) would then be given by:

$$E_e^{**} = \begin{bmatrix} p_e & 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} I - a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1}$$
$$\begin{bmatrix} Y_{ee} & Y_{ec} & Y_{eu} & Y_{ej} & Y_{ea} & Y_{eb} & Y_{er} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, \tag{9}$$

and the hypothetical labour income (L_e^{**}) would be:

$$L_e^{**} = \begin{bmatrix} w_e & 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} I - a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1}$$
$$\begin{bmatrix} Y_{ee} & Y_{ec} & Y_{eu} & Y_{ej} & Y_{ea} & Y_{eb} & Y_{er} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}. \tag{10}$$

Then the EXP_e and LXP_e are equal to:

$$EXP_e = E_e - E_e{}^{**}, \tag{11}$$

$$LXP_e = L_e - L_e{}^{**}. \tag{12}$$

Transforming (11) and (12) into relative measurements, for region m it follows that:

$$\frac{EXP_m}{E_m} = \frac{E_m - E_m{}^{**}}{E_m},$$

$$\frac{LXP_m}{L_m} = \frac{L_m - L_m{}^{**}}{L_m}.$$

In line with Johnson and Noguera (2012), *employment attributed to foreign final consumption* (*EXC*) and *labour income attributed to foreign final consumption* (*LXC*) are

obtained by cancelling out all the final demands of the foreign countries. For the European Union, the fictitious number of jobs (E_e^{***}) and labour income (L_e^{***}) are:

$$E_e^{***} = \begin{bmatrix} p_e & 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} I - a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1}$$
$$\begin{bmatrix} Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, \tag{13}$$

$$L_e^{***} = \begin{bmatrix} w_e & 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} I - a_{ee} & -a_{ec} & -a_{eu} & -a_{ej} & -a_{ea} & -a_{eb} & -a_{er} \\ -a_{ce} & I - a_{cc} & -a_{cu} & -a_{cj} & -a_{ca} & -a_{cb} & -a_{cr} \\ -a_{ue} & -a_{uc} & I - a_{uu} & -a_{uj} & -a_{ua} & -a_{ub} & -a_{ur} \\ -a_{je} & -a_{jc} & -a_{ju} & I - a_{jj} & -a_{ja} & -a_{jb} & -a_{jr} \\ -a_{ae} & -a_{ac} & -a_{au} & -a_{aj} & I - a_{aa} & -a_{ab} & -a_{ar} \\ -a_{be} & -a_{bc} & -a_{bu} & -a_{bj} & -a_{ba} & I - a_{bb} & -a_{br} \\ -a_{re} & -a_{rc} & -a_{ru} & -a_{rj} & -a_{ra} & -a_{rb} & I - a_{rr} \end{bmatrix}^{-1}$$
$$\begin{bmatrix} Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{ee} & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}. \tag{14}$$

Then the EXC_e and LXC_e are equal to:

$$EXC_e = E_e - E_e{}^{***}, \tag{15}$$

$$LXC_e = L_e - L_e{}^{***}. \tag{16}$$

Finally, transforming (15) and (16) into relative measurements for region m

$$\frac{EXC_m}{E_m} = \frac{E_m - E_m{}^{***}}{E_m},$$

$$\frac{LXC_m}{L_m} = \frac{L_m - L_m{}^{***}}{L_m}.$$

The measurements of the employment impacts of exports presented above help clarify the intricate networks that cause employment impacts worldwide. It should be noted that this method offers other possibilities that are not presented here but which can be applied by eliminating individually or in pairs or groups of countries the export elements in the inter-country model. In line with Los and Timmer (2018), the indices presented

Table 1 Aggregate Employment Data, 2014 Source: Author's calculations based on the WIOD

	Total variables		
	Employment (*E*) (million workers)	**Labour compensation (*L*) (trillion USD)**	**GDP (trillion USD)**
EU27	195.6	8.7	13.9
China	858.4	5.7	10.3
United States	155.8	9.8	17.3
Japan	61.2	2	4.4
Australia	11.9	0.8	1.4
Brazil	104.0	1.1	2.1
Other Countries	1074.9	8.0	13.7

here cover what may be considered the most useful measures for quantifying the economic impact of trade.

3 Database

The empirical application is based on the latest version of the World Input–Output Database (WIOD),[9] which contains data for 2014.[10] Originally, the WIOD comprises 56 sectors of production and 43 countries plus a residual Rest of the World (ROW). After aggregation of the original structure,[11] the empirical analysis shows six selected countries/regions (China, United States, the European UnionEU27-,[12] Japan, Brazil and Australia) plus a Rest of the World category that completes the world system.[13]

Information about the labour variables was obtained from the Socio Economic Accounts (SEA) contained in the World Input–Output Database. Specifically, the socioeconomic data of the WIOD provides the number of employees and the amount of labour compensation by sector and country. To be precise, however, the SEA does not cover information on the ROW countries, so this area had to be excluded from the calculations. The other countries in the SEA, which include eleven economies other than the six selected regions, have also been identified in this empirical application.[14] In all these regions, the amount of labour compensation (in local currencies) has been converted into US Dollars according to the conversion rates published in the WIOD.

Table 1 provides an overview of the employment statistics used. The indicators show a high degree of variability, and no general patterns can be traced. Unsurprisingly, since the economies have different production features the labour markets differ greatly. Moreover, the importance of labour indicators also depends on demographic patterns,

[9] Timmer et al. (2015) described the construction and structure of this database.

[10] The empirical application uses the same database as Los and Timmer (2018) to maintain an identical input–output structure.

[11] Although the aggregation of accounts introduces some bias, according to Miller and Blair (2009) spatial aggregation produces only 'modest aggregation bias.'

[12] The European Union includes the 27 countries that are currently part of the Union.

[13] The definition of aggregated economic areas provides clear and concise results on the main world economic blocs.

[14] This group includes Canada, Great Britain, India, Indonesia, Mexico, Norway, Russia, South Korea, Switzerland, Turkey, and Taiwan.

Table 2 Employment impact of direct exports, 2014. Source: Author's calculations based on the WIOD

	***EXD*(thousand workers)**	***LXD*(million USD)**	***EXD*/*E*(%)**	***LXD*/*L*(%)**	***LXD*/*GDP*(%)**
EU27	33,797	1,624,320	17.28	18.58	11.67
China	145,257	998,945	16.92	17.63	9.71
United States	11,698	874,566	7.51	8.95	5.04
Japan	7642	398,798	12.48	15.42	8.99
Australia	1659	117,585	13.98	15.00	8.66
Brazil	10,848	106,455	10.43	9.32	5.14

social structures, legal environments, and economic systems that largely determine the number of jobs and amount of labour income in the various countries.

Table 1 shows that (absolute) employment is highest in China and the Other Countries (858.4 million employees and 1074.9 million employees, respectively) and that it is lowest in Australia (11.9 million employees) and Japan (61.2 million employees). The figures for the other economies fall within this range.

The amounts of labour compensation and GDP also highlight the differences between countries, though the distance between these variables is lower than for physical employment. The United States leads in both labour income (9.8 trillion dollars) and GDP (17.3 trillion dollars). The European Union is next, with a labour income of 8.7 trillion dollars and a GDP of 13.9 trillion dollars. Unsurprisingly, the rankings of the countries are the same for both L and GDP: since labour compensation is a large component of domestic product and thus determines a large proportion of GDP, the importance of GDP is identical to that of L for all countries.

4 Employment impacts of gross exports

Table 2 shows the measurements of LXD and EXD described in Section "A Global Model of Employment Accounting," i.e., the (physical) employment and (monetary) labour income attributed to direct gross exports (left-hand side) and the percentages in relation to the observed values.

With regard to the figures for total employment, the number of jobs attributed to exports (EXD) varies greatly between countries. Specifically, removing exports from the model affects Chinese employment the most while the impact of this measure on employment in the EU and the US follows at a great distance. In contrast, if we look at labour income attributed to exports, the European Union is the most affected economy—much more than China, which occupies the second highest position in Table 2. Also worth mentioning is the labour compensation explained by US exports. All these findings highlight the wide disparities in the impacts of trade activity on domestic labour markets and provide an individualized view of the contribution of exports to employment.

In all regions, the relative measures in Table 2 are closer than the total trade-related variables. Three main results are observed among these indicators. First, the EXD/E and LXD/L ratios are very similar in all countries. This is not surprising since labour income is directly determined by the number of employees and the trade consequences therefore

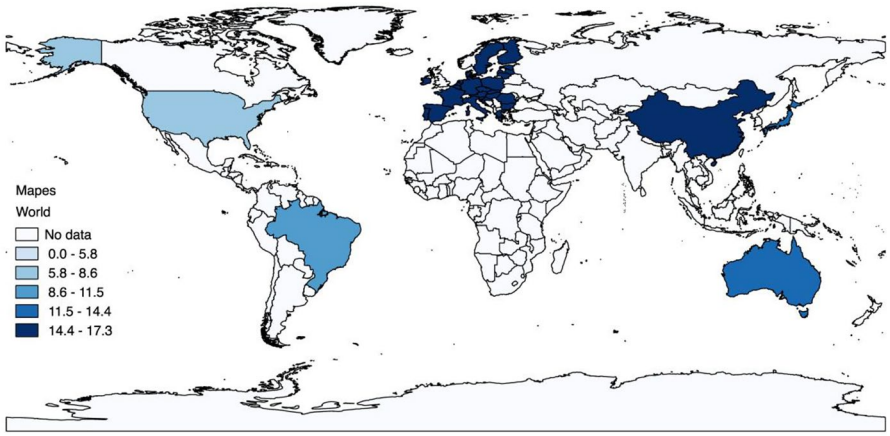

Fig. 1 Employment attributed to direct exports in relation to total employment (%), 2014. Source: Author's calculations based on the WIOD

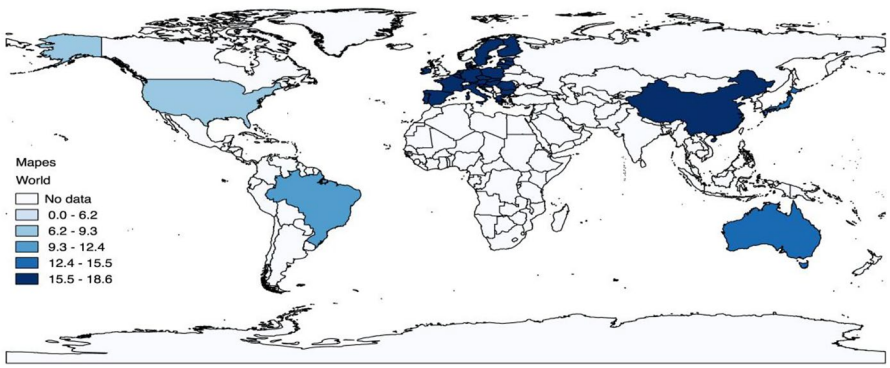

Fig. 2 Labour income attributed to direct exports in relation to total labour income (%), 2014. Source: Author's calculations based on the WIOD

show parallel impacts on the (relative) physical and monetary employment variables. Second, the United States and Brazil have the lowest percentages of all (7.51% of total employment and 8.95% of labour income for the US and 10.43% and 9.32%, respectively, for Brazil). These figures are well below those of the other countries. Third, the percentages for Australia and Japan are close to those for the EU (17.28% for jobs and 18.58% for labour compensation) and those for China (16.92% for jobs and 17.63% for labour compensation) (Fig. 1).

In summary, the impact of exports on the number of jobs and monetary income ranges from one-sixth (the EU and China) to less than one-tenth (the United States) of the (observed) benchmark values. These aggregated measures clearly demonstrate that the links between export activities and jobs at the domestic level are asymmetrical. Accordingly, the levels of exposure to the export-related impacts on employment affect countries differently, which may have consequences for employment creation and income distribution processes worldwide (Fig. 2).

Table 3 and Figs. 3 and 4 show the *LXP* and *EXP* interdependencies channelled through foreign final production. These indices are limited in order to show employment generated by exports used in final production abroad and thus exclude exports of final

Table 3 Employment impact of foreign final production, 2014. Source: Author's calculations based on the WIOD

	***EXP*(thousand workers)**	***LXP*(million USD)**	***EXP*/*E*(%)**	***LXP*/*L*(%)**	***LXP*/*GDP*(%)**
EU27	18,073	879,662	9.24	10.06	6.32
China	64,677	466,618	7.53	8.24	4.54
United States	7440	550,763	4.78	5.64	3.17
Japan	4414	227,162	7.21	8.78	5.12
Australia	1290	94,877	10.87	12.11	6.99
Brazil	7930	76,720	7.62	6.72	3.70

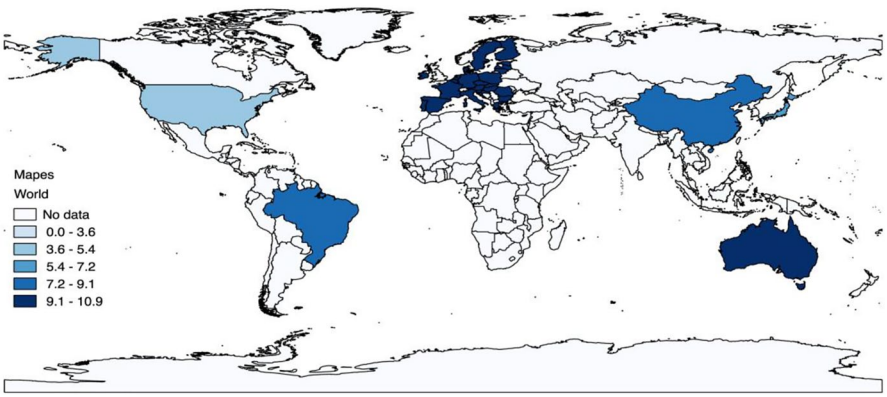

Fig. 3 Employment attributed to foreign final production in relation to total employment (%), 2014. Source: Author's calculations based on the WIOD

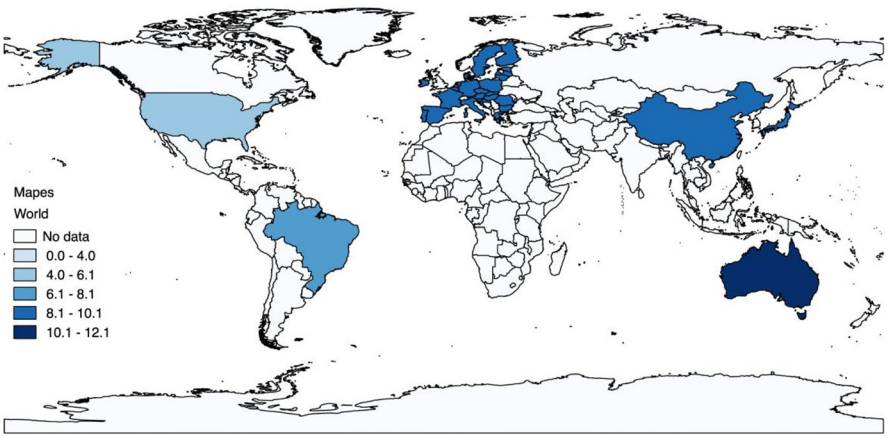

Fig. 4 Labour income attributed to foreign final production in relation to total labour income (%), 2014. Source: Author's calculations based on the WIOD

products. This explains why the values in Table 3 are much lower than the corresponding values in Table 2.

Foreign final production affects Chinese employment the most. At a great distance follows its impact on employment in the EU and the United States. As for LXD, the labour income attributed to foreign final production in the European Union shows

Table 4 Employment impact of foreign final consumption, 2014. Source: Author's calculations based on the WIOD

	***EXC*(thousand workers)**	***LXC*(million USD)**	***EXC*/*E*(%)**	***LXC*/*L*(%)**	***LXC*/*GDP*(%)**
EU27	32,845	1,577,619	16.79	18.04	11.33
China	141,960	974,015	16.54	17.19	9.47
United States	11,251	840,327	7.22	8.60	4.84
Japan	7559	394,472	12.34	15.25	8.89
Australia	1650	116,934	13.91	14.92	8.62
Brazil	10,805	105,980	10.39	9.28	5.12

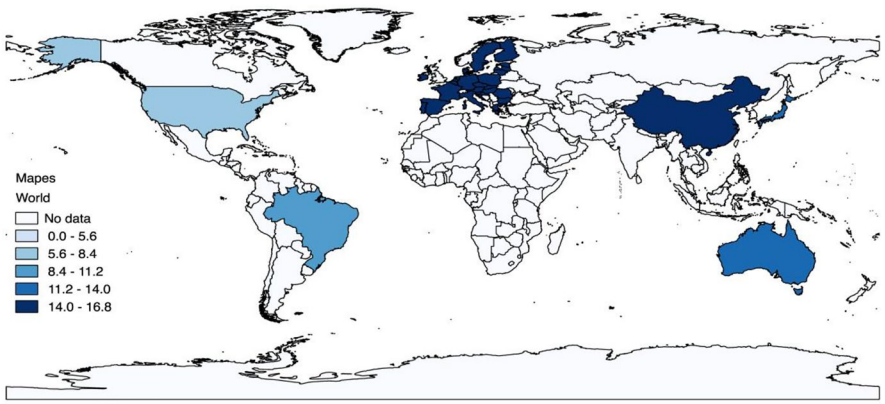

Fig. 5 Employment attributed to foreign final consumption in relation to total employment (%), 2014. Source: Author's calculations based on the WIOD

the highest value, while the second position in Table 3 is now occupied by the EU and the third position is occupied by China.

The relative measures in Table 3 reveal great variation between countries. *EXP/E* ranges from 4.78% in the US to 10.87% in Australia, while similar (though slightly higher) relative values are observed for labour income (*LXP/L*) for all countries.

Employment attributed to production ultimately consumed abroad (i.e., measurements *EXC* and *LXC*) is illustrated in Table 4 and Figs. 5 and 6. Again, the *EXC* and *LXC* are lower than the corresponding *EXD* and *LXD* for each country, since the former are limited to impacts due to a country's production consumed abroad. Note, however, that the differences between the employment impacts of direct exports (i.e., *EXD* and *LXD*) and *EXC* and *LXC* are small, since the difference is the value added returning to the home country embedded in the imported products, which are contained in the former but not in the latter. Again, EXC affects Chinese employment the most followed, at a great distance, by its effects on EU and US employment. The labour income attributed to foreign final production (*LXC*) is highest in the European Union and well above the figures for China in the second position in Table 4 and the US in the third.

Table 4 also shows the relative measures of employment impact attributed to foreign final consumption. The US has the lowest values for *EXC/E* and *LXC/L* (7.22% and 8.60%), while the EU has the highest (18.04% and 11.33% respectively).

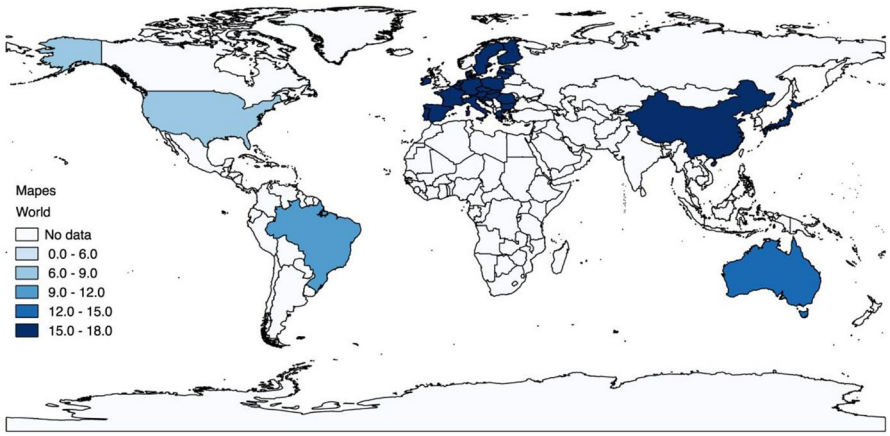

Fig. 6 Labour income attributed to foreign final consumption in relation to total labour income (%), 2014. Source: Author's calculations based on the WIOD

By comparing the proposed employment measures, we can see how the elements in the model that reflect export activity (i.e., direct exports, foreign final production, and foreign final consumption) contribute to generating occupation and labour income. The analysis also reveals (significant) quantitative differences in the absolute values of employment and labour revenues in the countries analysed, while the relative indices show lower disparities between countries.

5 Conclusions

Numerous contributions have adopted different points of view and alternative methodological tools to analyse trade-related consequences for domestic economies. One branch of literature analyses the links between jobs and income in an interconnected world. In this paper, for example, the multi-country input–output model is used to evaluate the impacts of gross exports on labour. Unlike product-oriented contributions, which calculate the value added of exports, the hypothetical extraction method is used to obtain employment impacts—specifically, the (physical) number of jobs and the (monetary) labour compensation.

The results reported in this paper show that the significance of export activity is different in the various countries, with the United States showing the lowest capacity of exports to create employment and the European Union and China showing the highest.

From a policy perspective, for several reasons it is crucial to understand the underlying processes that help generate employment and labour income worldwide. First, employment is a necessary condition for achieving economic and social stability. Second, employment contributes to *quantitative* economic growth since high employment means that a large number of goods are produced. Third, employment can also contribute to *qualitative* economic growth, especially if occupation is linked to an inclusive economy, since it improves people's living standards and welfare. Since the method described in this paper can be used to calculate the employment impacts of a country's exports and the transmission of the effects worldwide, it is undoubtedly of interest for economic policy in general and for labour policy in particular.

To increase our understanding of the impacts of trade flows on domestic employment and incomes, methods that can capture the underlying mechanisms behind impacts on labour are essential. In particular, in a context of product fragmentation and increasing production connections around the world, it is important to have accurate evaluation tools for quantifying the links between jobs and income in the interconnected world. Although the analysis is aggregated and limited to major countries, this article shows that the complexity of global production can be made compatible with an analysis of the trade-related labour impacts on domestic economies. Since more recent databases are expected in the next few years, it will be possible to update the method used in this paper. Alternative databases can also be used to test the accuracy that must be attributed to employment outcomes. Improved databases will also enable us to investigate impacts on employment in national economies more thoroughly. In particular, combining the interconnections of world production with information on labour qualification levels, gender and other social characteristics of workers, once available, will provide a rich avenue for future research.

Acknowledgements
The author gratefully acknowledges financial support from the Rovira i Virgili University (Grant PFR2021). This research was conducted during a year of sabbatical leave granted by the Rovira i Virgili University. The author is grateful to Dr Josep Maria Arauzo-Carod for editing assistance. Helpful comments and suggestions by two anonymous reviewers have substantially improved an earlier version of the manuscript.

Author contributions
MLL carried out all the analysis, i.e., she conceived the idea and objectives, constructed the multi-regional model and applied the method empirically. The author read and approved the final manuscript.

Funding
This work was supported by the Rovira i Virgili University (Grant PFR2021).

Data availability
The data underlying this article were obtained from publicly data (www.wiod.org).

Declarations

Competing interests
The author declares no competing interests.

Received: 9 June 2022 Revised: 3 November 2022 Accepted: 4 November 2022
Published online: 23 November 2022

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