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Trade and employment in a vertically specialized world

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Abstract

With the steady growth of global production networks, each country's trade now has a more complex relation to the international division of labour. This paper decomposes the employment effects of a country's trade into five components, specifically the labour content (1) in exports, (2) in imports, (3) in the import content of exports, (4) in the export content of imports, and (5) in intermediates contained in imports from a third country. The last three components are strictly due to a country's participation in global production networks. Based on the countries included in the panel, the analysis shows that in 2009 about 88 million jobs were generated worldwide through their participation in global production networks (GPN) trade, which is about 14 per cent of the total number of jobs generated by international trade. Countries that demanded the most labour as a result of GPN trade are the large developed economies with the exception of China. With regard to the import content of exports, the analysis shows that in 2009, it led to the demand for about 44 million jobs within the 39 countries. Third-country intermediates contained in imports[1] generated labour demand of about 39 million jobs and the export content of imports created demand for about 5 million jobs.

Keywords: employment, global production networks, input-output analysis, international trade, vertical specialization

JEL classification: F13; F14; F66; O11

1 In the paper it is referred to as "Third-country Intermediates Trade".

1 Introduction

The relation between trade and employment has been an important subject of inquiry for economists and policy makers. International trade economists have recognized the importance of global production networks (GPN) for trade theory and for the measurement of trade, but there has been little systematic research on the employment effects of trade in GPN. Participation in GPN is often characterized by countries specializing in some particular segments *of production processes* instead of final products. Empirically, such phenomenon is documented by steady increase of "trade in intermediates", or "vertical specialization" when traded intermediates are used for further exporting[2] (Gereffi, 1994; Jiang and Milberg, 2012).

With the prevalence of trade in GPN, the relation between trade and employment becomes more complicated. The labour content associated with a country's foreign trade is no longer simply of two kinds – (1) domestic labour contained in exports and (2) foreign labour contained in imports. With the addition of GPN trade, there are three more categories of employment to consider – (3) foreign labour contained in exports, (4) domestic labour contained in imports, and (5) third-country labour contained in a country's imports. Recent publication of a World Input-Output Database (WIOD)[3] allows us to calculate all five categories of employment generated by trade over the period 1995-2009 for a panel of countries that cover 85 per cent of world GDP.

The paper is structured in the following way. Section 2 provides a brief review of relevant literature. Section 3 presents the method of global factor content analysis, which is adopted to compute the employments generated by trade in GPN. Section 4 introduces the WIOD and points out the appropriateness of applying the method of global factor content analysis to this dataset. Section 4 analyses the results of the global factor content calculations, and by doing so an attempt is made to connect trade and employment analysis with the recent literature on GPN. The final section discusses some of the policy implications of this paper.

2 Literature review

There is an immense literature that explores the relationship between foreign trade and employment. There has also been an extensive survey of theories and methodologies conducted to study this relation (Gibson, 2011). In general, the methods can be grouped into following categories: econometric methods, computational and simulation methods, factor-content methods, partial equilibrium methods, input-output methods, linear programming methods, and finally, qualitative methods. The method adopted in the present paper is a combination of factor-content and input-output methods. There are three reasons behind adopting this method. First, the research question itself demands a method that enables the extraction of labor contents embedded in intermediate trade flows across all industries for each country. Second, the standard practice of decomposing trade flows into intermediate and final goods traded are input-output based. Third, the dataset this paper relies on is a set of international input-output tables. These reasons will be made much clearer as we proceed to Section 3 of this paper.

[2] For example, Miroudot et al. (2009) report that trade in intermediates accounted for almost 60 percent of world trade in goods in 2007, up from just over 50 per cent in 1999.

[3] See Timmer (2012) for the details on the WIOD.

The input-output factor-content method has been adopted by other researchers to address research question that are related to ours. Here, we briefly discuss a couple of representative ones. Wood (1995) conducted the factor-content calculation of the change in labor demand in developed countries due to trade. According to him, for developed countries, trade drastically reduces demand for unskilled labors but has somewhat positive effects on skilled labor demand, which in turn contributes to the widening of domestic inequality. Kucera and Milberg (2003) use input-output analysis to calculate the effect of trade expansion on manufacturing employment for OECD countries. The authors' results demonstrates that, contrary to conventional view, the employment "losses" from trading with non-OECD countries were mostly not due to import penetration from low-wage countries, but due to a decline of exports to the low-income markets.

More recently, due to the prevalence of vertical specialization and international division of labor, the literature explaining, theorizing, and measuring trade in intermediates in GPN have been springing from academia, policy institutes and international organizations. Miroudot et al. (2012) provides detail review of empirical evidence on the integration of global production processes. Their review brings out that for measuring trade in intermediates, there are specifically two standard methodologies. The first methodology relies on breaking down of disaggregated trade flows and distinguishing intermediates from final goods according to their uses. For example, Bergstrand and Egger (2008) use the broad economic categories classification to capture traded intermediate goods. The second methodology relies on national input-output tables including import intermediates table. Hummels et al. (2001) was the first who proposed the input-output based measure of a country's trade dependence on foreign intermediates which quickly became widely adopted in the field. Later, Koopman et al. (2010) proposed another popular measure which is more data-intensive but requires less assumptions.[4]

Empirical literature trying to link employment with trade in intermediates in GPN have been quite thin. A systematic multi-country empirical approach was absent from the literature until most recently mainly due to the lack of appropriate datasets.[5] Since the recent publication of World Input-Output Database (WIOD), articles trying to empirically assess the relation between employment and trade in intermediates have been emerging. Los et al. (2012) estimated Chinese factor incomes and employment since 1995 by taking trade in intermediates with other countries into account. Stenhrer et al. (2012) investigated the pattern and change of value-added trade and factors in trade for the panel of countries covered in the WIOD. They found that domestic value-added content of exports tend to decrease over time and increase again in the crisis; and developed countries tend to be relatively stronger net exporters of high-educated labor in value terms. Timmer et al. (2012) calculate income and jobs related to activities carried out in countries that are directly and indirecly involved in production of final manufacturing goods, and define them as global value chain (GVC) jobs and incomes. They find that, in contrast to popular fear, international fragmentation does not necessarily lead to destruction of GVC jobs in advanced countries.

Unlike the literature discussed above, the present paper focuses on the employment effect of countries' participation in GPN exclusively. We decompose the employment effects of a country's trade into the

4 For example, unlike Hummels et al. (2001), Koopman et al. (2010)'s measure no longer relies on the "proportionality assumption" (assuming the sectoral intensity of using imported intermediates is proportional to the intensity of using total intermediates).

5 It will be explained in the next section that to conduct such analysis, there must be a global dataset that is highly harmonized, contains bilateral trade data on both final and intermediate goods, and includes employment data. The recently published WIOD happens to meet all these requirements.

five components as mentioned in the introduction, and define the last three components as the ones that are strictly due to a country's participation in GPN. The pattern and evolution of these components are observed, assessed and compared across the countries in this paper on an aggregate level using the WIOD.

3 Model and methodology

This paper tries to link the idea of trade and employment with the recent literature on vertical specialization. Since the empirical method for vertical specialization is grounded in input-output framework,[6] and the WIOD is a database of input-output tables, so, the method we adopt in this paper is of input-output nature by necessity. In this section we first introduce a single-country input-output model of trade and employment without intermediate trade. Intermediate trade is then introduced into this single country model. Finally, the model is extended to three countries trading amongst themselves with both final and intermediate goods. The model consists of at least three countries because foreign country's exports to home country also contain imported intermediates from another foreign country.

3.1 Single-country without intermediate trade

The basic input-output relation of a country is shown as in Equation (1):

$$Y = AY + F \tag{1}$$

In (1), A is the input-output technical coefficient matrix, Y is a vector of total outputs, and F is the vector of final demands. Equation (1) can be rearranged into an open Leontief model as shown in Equation (2):

$$Y = [I - A]^{-1}F \tag{2}$$

Here, $[I - A]^{-1}$ is the Leontief inverse matrix, and multiplying it by a vector of final demands F will give us the vector of domestic outputs that is required in order to produce this vector of final demands. The idea behind this relation is simple – in order to produce the vector of final demand, intermediate goods have be produced and used-up.[7]

In Equation (2), we incorporate trade and employment into the input-output system and we get,

$$L = \hat{E}[I - A]^{-1}X \tag{3}$$

The two new elements in Equation (3) are, exports (X), and a diagonal matrix of labour coefficients ($\hat{E}$). Essentially, since exports are part of a country's final demand, multiplying it with the Leontief inverse matrix will give us the total amount of domestic outputs that is stimulated by X amount of exports demand. Finally, since labour coefficient tell us how much domestic labour is required for a unit of domestic output, then, multiplying $[I - A]^{-1}X$ with a diagonal matrix of labour coefficients will extract the total (direct and indirect) labour content due to this vector of exports. This is also the reason why this method is called the factor-content analysis.[8] This method was first introduced by Chenery and

[6] See Hummels et al. (2001), Koopman et al. (2010), WTO (2011), Escaith et al. (2010), and Meng et al. (2011).
[7] For the mathematical derivation and property of Leontief inverse matrix, see Miller (2009).
[8] See Miller (2009) and Gibson (2011) for detailed introductions to this methodology.

Watanabe (1958), and subsequently used extensively by Lydall (1975). There can be many variations of this model depending on the research question.[9] The vector that multiplies the Leontief inverse matrix can also be a vector of changes, which will yield changes of employments due to trade changes over a period of time.

For the purpose of calculating employments generated by trade, this model has two defects (in addition to the ones that are typical to any traditional input-output models).[10] First, if the country's exports contain large amount of import contents, then, this model will over-estimate the employment effect of trade. Second, in the case of a single-country model this model is silent about the employment effect of country's trade in foreign countries.

3.2 Single-country with intermediate trade

With the existence of intermediate trade, a simple twist is added to Equation (3). Imagine that the country's input-output data contains two separate tables: domestic intermediate basic flow table (Z^D), and imported intermediate basic flow table (Z^M). Each element in the imported basic flow matrix z_{ij}^M indicates the amount of intermediates used by sector j that is imported from rest of the world's sector i. The two separate basic flow matrices will allow us to construct two separate input-output coefficient matrices: the domestic (A^D) and imported (A^M), and the sum of these two will be the traditional A matrix.

With the A^M matrix, firstly, Equation (3) can be adjusted so that the labour content will be the domestic labour content embodied in this country's exports, and this is done by substituting A with A^D. One can imagine that this would shrink the Leontief inverse matrix into a domestic Leontief inverse matrix, so the domestic employment effects due to exports will be adjusted accordingly. Moreover, with the A^M matrix, we are now able to compute the import content of a country's exports in following way,

$$IC = A^M[I - A]^{-1}X \tag{4}$$

Hummels et al. (2001) was the first to develop this algorithm. In their work, they propose to measure the degree of vertical specialization by expressing IC in terms of exports. Therefore, vertical specialization is how much foreign intermediates are required for each unit of exports. Alternatively, Koopman et al. (2010) propose to measure vertical specialization by dividing IC by the total value directly and indirectly generated by a country's exports. Thus, for Koopman et al. vertical specialization is the share of foreign intermediate inputs value in the total integrated value generated by a country's exports. However, in this paper we focus on the imported content itself rather than expressing it as a ratio to some other variable.

Again, since this is still a single-country model, the import content consists of exports from rest of the world aggregated. Therefore, there will be no way of extracting the foreign labour content in this country's vertical specialization. Furthermore, if we allow the existence of imported intermediates, then, the imports from rest of the world to this country will also contain intermediates from this country itself, this in turn will create upward biasness for the effect of foreign imports on domestic employments. As

[9] Kucera and Milberg (2000, 2003) and Jiang (2013) have constructed trade-expansion vector (instead of the export vector) to study the effect on employment due to a country's change of trade structure.

[10] See McGregor et al. (1996), Gibson (2011), and Jiang (2013).

we will see in the next subsection, these two defects will be solved by a multi-countries (global) input-output model.

3.3 Multi-countries with intermediate trade

A multi-country model is essentially a regional input-output model on global scale. Here we briefly introduce the model, but details can be found in Miller and Blair (2009). Assuming there are three countries (1, 2, and 3) in the world, trading in both intermediates and final outputs with each other. Let A^{ij} be the imported intermediate coefficient matrix, intermediates are exported from country i and used by country j. When $i = j$, it becomes the domestic input-output coefficient matrix. Following the system of three equations the final demands of the three countries can be expressed in the following way,

$$\begin{aligned} Y^1 - A^{11}Y^1 - A^{12}Y^2 - A^{13}Y^3 = f^1 \\ -A^{21}Y^1 + Y^2 - A^{22}Y^2 - A^{23}Y^3 = f^2 \\ -A^{31}Y^1 - A^{32}Y^2 + Y^3 - A^{33}Y^3 = f^3 \end{aligned} \quad (5)$$

System (5) states that, for each country, final demand is the residual of total outputs minus domestic and exported intermediates.[11] If we collect the terms and rearrange the system into a system of partitioned matrix multiplication, we yield Equation (6) below,

$$\begin{bmatrix} I - A^{11} & -A^{12} & -A^{13} \\ -A^{21} & I - A^{22} & -A^{23} \\ -A^{31} & -A^{32} & I - A^{33} \end{bmatrix} \cdot \begin{bmatrix} Y^1 \\ Y^2 \\ Y^3 \end{bmatrix} = \begin{bmatrix} f^1 \\ f^2 \\ f^3 \end{bmatrix} \quad (6)$$

At this point, one can easily see that the multi-countries input-output system is almost identical with the single-country system except that scalars are now replaced with matrices. If we factor out the identity matrices from the left of Equation (6) and move them to the right hand side, then we obtain a global Leontief inverse matrix:

$$\mathrm{L}^G = \left[\begin{bmatrix} I & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & I \end{bmatrix} - \begin{bmatrix} A^{11} & A^{12} & A^{13} \\ A^{21} & A^{22} & A^{23} \\ A^{31} & A^{32} & A^{33} \end{bmatrix} \right]^{-1} = \begin{bmatrix} l^{11} & l^{12} & l^{13} \\ l^{21} & l^{22} & l^{23} \\ l^{31} & l^{32} & l^{33} \end{bmatrix} \quad (7)$$

This global Leontief inverse matrix L^G is of great importance. This is a $n \times n$ matrix with $n = 3 \times m$, and m is the number of sectors. At this stage, we partition this matrix into a 3 by 3 partitioned matrix for future use. As a partitioned matrix, it contains 9 small matrices each of dimension $m \times m$. This matrix multiplies a partitioned vector (where the partitioning is done in the same order as the three countries) of final demands, which will give us the total outputs for each country that are required to produce that vector of final demands directly and indirectly.

To construct the trade vector for the home country, we follow the method proposed by Stehrer et al. (2012). Suppose if country 2 is the home country, then from country 2's perspective, the exports from countries 1 and 3 would be its imports, and its own exports will be countries 1 and 2's imports. Let T_i $(3 \times m)$ be the trade vector from the perspective of country 2. At position 2, it will be the vector of country 2's exports, and at positions 1 and 3, there will be the vector of country 1 and 3's exports

11 For example $A^{11}Y^1$ is country 1's domestic intermediates, and $A^{12}Y^2$ is the intermediate use of country 1's exports by country 2.

respectively. Multiplying the global Leontief inverse matrix by the trade vector T_i will give us the total value generated by country 2's foreign trade globally. The subscript i denotes the home country and essentially Equation (8) is the second half of Equation (2) but on multi-regional (global) level.

$$\zeta_i = L^g \cdot T_i \tag{8}$$

As mentioned in the introduction, multi-countries trade with the existence of intermediate trades contains five components, *exports* and *imports* of final goods, *import content of exports*, *export content of imports*, and *third-country intermediate contents in home country's imports*. Equation (8) cannot help us to decompose the trade into these five components because matrix multiplication would aggregate all the rows. So we construct matrix Θ, using the partitioned global Leontief inverse matrix (7) and we get,

$$\Theta_2 = \begin{bmatrix} l^{11}t_1 & l^{12}t_2 & l^{13}t_3 \\ l^{21}t_1 & l^{22}t_2 & l^{23}t_3 \\ l^{31}t_1 & l^{32}t_2 & l^{33}t_3 \end{bmatrix} \tag{9}$$

Essentially, Θ_2 is constructed by multiplying l^{kj} $(m \times m)$ by t_j $(m \times 1)$ at each position; in this way, Θ_2 is of dimension $m \times 3 \times 3$, with each sub-matrix of dimension $m \times 1$. Matrix Θ_2 is of great importance because it contains the five components of country 2's trade. Again, t_1 and t_3 are exports from countries 1 and 3 to country 2, and t_2 is the exports from country 2 to countries 1 and 3.

Let us begin with the diagonal items. The diagonal items are total value generated by country 2's final goods exported (position {2, 2}), and countries 1 and 3's final goods exported to country 2 Positions {1, 1} and {3, 3}). At this stage, the first two components of country 2's trade are identified and calculated.

The vertical elements up and down from the "home position" {2, 2} are foreign values generated from country 2's intermediate use of countries 1 and 3's exports. Let us take $l^{12}t_2$ as the example. Since A^{12} is the technical coefficient matrix for country 2's intermediate use of exports from country 1, the corresponding Leontief inverse matrix l^{12} will give us the value generated for country 1 for each unit of home country's intermediate input demand. Consequently, $l^{12}t_2$ would be the total value generated in country 1 due to home country's exports. Thus we can generalize it by stating that the vertical elements up and down from the home position (but excluding the home position itself) are import contents of exports for the home country, and the sum of those elements divided by home country's exports ($u \cdot t_2$ where u is the column summation vector) would be the measure of vertical specialization à la Hummels et al. (2001); whereas dividing the sum of those elements by the total value generated by country 2's exports[12] would be the measure of vertical specialization à la Koopman et al. (2010).

Following the same logic, the horizontal elements left and right from the home position are total value generated in the home country due to country's 1 and 3's exports, channelled through foreign demand of home country's exports as intermediates. In other words, those elements can be called the "export content of imports" from the home country's perspective, or others[13] call it "re-exports". The sum of

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[12] From Equation (9), the value would be $u \cdot \begin{bmatrix} l^{12}t_2 \\ l^{22}t_2 \\ l^{32}t_2 \end{bmatrix}$ where u is the summation vector of dimension $m \times 3$.

[13] Koopman et al. (2010) and Stehrer et al. (2012)

those elements divided by country 2's imports (or row sum of the home position) could be a measure of "horizontal specialization" – the degree of domestic export contents of foreign imports, although this term has not appeared in the literature yet.

The rest of the elements in the Θ_2 matrix ({1, 3} and {3, 1}) are values generated in country 1 due to country 3's production of exports for country 2, and vice versa. It is also to be noted that country 3 demands goods and services from country 1 as intermediates. For example, if a country imports cheese from a foreign country, but this foreign country imports milk from a different foreign country as an intermediate input, then such trade generates additional trade when the cheese maker imports milk from abroad. We call this component the "third country intermediates trade" because it is two countries' trade that generates income in a third country. At this stage, the five components of total values generated by a country's trade are identified and explained.

Finally, we could add the employment dimension to this model. Following the factor-content method introduced in 2.1, let $\widehat{E_i}$ be the diagonal matrix of labour coefficients for country i. We multiply each partitioned row $(m \times 1)$ of the $\Theta_2$matrix by the corresponding $\widehat{E_i}$ $(m \times m)$ matrix, the Θ_2 matrix is transformed into an employment matrix of Λ_2 as shown in (10) below:

$$\Lambda_2 = \begin{bmatrix} \widehat{E_1} l^{11} t_1 & \widehat{E_1} l^{12} t_2 & \widehat{E_1} l^{13} t_3 \\ \widehat{E_2} l^{21} t_1 & \widehat{E_2} l^{22} t_2 & \widehat{E_2} l^{23} t_3 \\ \widehat{E_3} l^{31} t_1 & \widehat{E_3} l^{32} t_2 & \widehat{E_3} l^{33} t_3 \end{bmatrix} \tag{10}$$

Since columns are the "purchases" and rows are the "sales", then, each labour coefficient matrices should be multiplied across the corresponding partitioned row. Λ_2 is the matrix of employments generated by home country's trade, and the employments generated by the five components of trades are shown in the same order as the five types of values generated in matrix Θ_2. To summarize, in a world with internationalized production processes, there are five distinct channels through which a country's trade can affect employment globally. Two channels are the standard impact of final goods and services exports and imports. The last three channels are uniquely the result of countries' participation in GPN. Each channel produces income and labour demand, domestically or internationally. Exports and the export content of imports generate demand for domestic labour. Imports, the import content of exports, and third-party intermediates trade generate demand for foreign labour.

Matrix Λ_n sheds new light on our understanding of the relation between trade and employment. Traditional theory only focuses on the diagonal items of the Λ_n matrix – final exports and imports. However, in this framework, the off-diagonal items are also important because they are the results of home country and its trading partners' participations in GPN.

3.4 Shortcomings of input-output factor content analysis

Finally, a few words should be said about the shortcomings of input-output factor content method. The shortcomings mainly come from series of restrictive assumptions behind it, and these assumptions can be summarized into following two points. First, it assumes that factor-content remains fixed over a long period of time. Thus, the results obtained from input-output method will fail to take into account changes in technology, tastes, policy and micro behaviours for the timeframe under consideration. Second, it assumes that productivity of the economy is exogenously given. With this assumption, the results will be silent about the kind the employment effect that is channelled through productivity change due to trade (McGregor et al., 1996; Gibson, 2011).

Despite these shortcomings, since the input-output tables in the WIOD are updated annually, the aforementioned two assumptions are not excessively problematic for our research question. The results obtained from applying this methodology will be countries' employment effects of trade assuming each country's tastes, policy, and micro behaviours stay the same and there was no productivity-inducing trade from year to year. The results will indeed deviate from the results generated by a method (such as CGE) that takes into account the changes of those variables, but the input-output results are still insightful to our research questions given these assumptions.

4 The World Input-Output Database (WIOD)

Prior to the publication of the World Input-Output Database (WIOD), researchers working in the area of vertical specialization had to start with a set of input-output tables that are not harmonized, and often the imported intermediate matrix had to be imputed by assuming proportionality.[14] Subsequently they had to develop various algorithms[15] to harmonize the input-output tables especially if they intend to conduct international comparisons. The newly published World Input-Output Dataset (WIOD) makes it possible to directly calculate labour demand according to our five-part decomposition for many countries for the years 1995-2009.

WIOD represents a huge advance in internationally-comparable data, providing not only bilateral final goods and services trade data by sector, but also data on trade in intermediate goods and services by sector. In order to know how much employment is generated from trade, we first have to know how much income is generated from trade using input-output analysis. Calculating the import content of exports (vertical specialization) also requires the input-output framework.[16] The WIOD also contains employment data consistent with the input-output sector specifications.

The WIOD has several unique features. First, it provides input-output tables and bilateral trade data for 40 countries, which comprises eighty-five per cent of world GDP. Second, all the data are harmonized into 35 input-output sectors, making cross-country comparisons possible. Third, the bilateral trade data are split into intermediate and final goods traded, and traded intermediates are reported as intermediate trade in the basic flow matrix for each country. Fourth, a separate account called the Social Economic Accounts contains employment data in terms of number of persons engaged, and total hours worked by skill types for every country and each of the 35 sectors. With these accounts, we can calculate labour coefficients, which allow us to extract labour content embodied in incomes generated by trade. Last but not the least, all of the data from this database is provided annually for the 15-year period, 1995–2009.

The calculation requires that all countries' input-output tables have the same dimensions; this requirement forces us to drop some countries and sectors from the dataset. We dropped Luxembourg because it produces no outputs for many of the sectors specified by the WIOD. The two sectors that were taken out from each country are "Sale, Maintenance and Repair of Motor Vehicles and Motorcycles", and "private Households with Employed Persons". The final calculation thus includes 39 countries and 33 sectors.

[14] See Winkler and Milberg (2009).
[15] See Koopman et al. (2001) for an example of such algorithm.
[16] See, Hummels et al. (2001), Koopman et al. (2010), WTO (2011), Escaith et al. (2010), and Meng et al. (2011).

5 Empirical results: Employment demand from trade

5.1 Employment demand in 2009

Table 1 presents the total employment generated in each of the five components of trade for the most recent year – 2009 – for each of the 39 countries. Sector-level information has been aggregated to a single employment figure for each country. We can view the total *domestic labour demand* for each country as the sum of labour demand by domestic exports and domestic content of imports. The sum of the rest is counted as the total *foreign labour demand* resulting from each country's trade position in 2009. If we sort the list by the difference between total domestic and foreign labour demand, we can see that, in 2009, most of the countries have demanded more foreign labour than domestic labour through exports. The countries with the largest positive difference between domestic and foreign labour demand are China, India, Indonesia and Brazil, the four large emerging developing economies in our panel of 39 countries. On the other hand, the countries with greatest negative difference between domestic and foreign labour demand are the USA, Germany and Japan, the three largest developed economies. It is perhaps worth pointing out here that these rankings do not necessarily correlate with the ranking of trade balances for these countries. The amount of jobs generated by the trade flow in a particular country's particular sector would depend on multiple factors such as the labour intensity of that sector and how integrated this sector is with the rest of the economy of that country. To further demonstrate this point, we calculated the Spearman and Kendall rank correlation coefficients for the list of net domestic jobs demanded and the list of net exports, and the results end up being negative and insignificant (-0.078 for Spearman and -0.084 for Kendall). These results show that the ranking of countries' net domestic job demands do not correlate with the ranking of countries' trade balances.

The results in Table 1 can be broken out into labour demand from final goods trade and labour demand from trade in intermediates, i.e. the results of GPN participation. The first category is the sum of the imports and exports columns in Table 1, and the sum of the other three columns is the second category. The results are shown in Table 2 below, sorted by labours demanded through GPN trade in descending order.

On the aggregate level, final goods trade generated demand for about 538 million jobs in 2009, and GPN trade produced demand for about 88 million jobs for our panel of 39 countries. At the level of individual countries, the countries that demanded highest amounts of labour from GPN trade are Germany, USA, China, Netherland, and France. That is, large and developed countries tend to be most responsible for GPN-based labour demand, and the only emerging developing economy that comes close to them in this respect is China. This distinguishes China from other emerging developing economies such as India, Brazil, Indonesia and Mexico. We can conclude that while it has expanded its foreign trade, China is actively engaged in GPN, just like the major industrialized economies.

Table 1 Jobs generated by five components of foreign trade 2009 (in thousands)

	Domestic Labour			Foreign Labour		
	Exports	Export content of Imports	Imports	Import Content of Exports	Third Party imports in imports	Differences (Domestic - Foreign)
China	140,249.1	3,270.9	17,462.8	4,221.9	2,238.0	119,597.4
India	34,914.8	89.6	8,064.4	1,291.5	496.6	25,151.9
Indonesia	10,236.6	24.0	3,891.8	448.4	289.0	5,631.4
Brazil	7,143.3	21.9	3,210.6	168.8	486.7	3,299.0
Bulgaria	882.3	1.4	465.3	97.9	98.2	222.4
Romania	1,597.0	6.0	1,097.3	186.6	293.7	25.4
Latvia	162.2	0.7	161.0	23.1	51.4	-72.5
Estonia	160.1	0.3	155.0	50.5	39.2	-84.3
Malta	45.1	0.0	119.0	33.9	23.8	-131.5
Cyprus	34.8	0.0	143.4	14.1	35.4	-158.1
Lithuania	250.5	1.0	383.8	102.7	68.5	-303.5
Slovenia	223.8	0.4	345.2	113.5	106.5	-340.9
Mexico	6,054.1	46.7	4,317.6	1,590.4	848.1	-655.2
Portugal	797.8	4.2	1,122.8	218.7	353.3	-892.8
Slovak	738.4	4.9	977.2	458.0	264.7	-956.6
Poland	3,592.6	26.9	3,149.1	911.0	747.0	-1,187.6
Hungary	1,129.2	5.8	1,349.1	713.2	417.8	-1,345.1
Finland	433.5	2.0	1,644.0	449.7	323.2	-1,981.4
Czech	1,674.7	15.9	2,176.4	993.2	544.1	-2,023.2
Turkey	2,056.6	6.2	3,146.6	456.5	506.2	-2,046.5
Greece	204.9	0.8	1,807.2	83.4	386.6	-2,071.5
Demark	529.4	3.4	1,974.9	463.1	542.5	-2,447.7
Taiwan, China	3,119.7	23.2	3,807.2	1,681.9	517.2	-2,863.4
Russia	6,532.3	47.3	8,398.5	225.3	897.5	-2,941.7
Ireland	578.8	2.4	2,278.2	897.9	440.0	-3,034.9
Sweden	828.5	6.7	2,520.9	697.5	694.6	-3,077.8
Austria	942.3	8.9	2,575.1	734.4	739.2	-3,097.4
Belgium	1,325.9	17.3	4,281.9	1,793.5	1,326.9	-6,059.2
Australia	1,081.5	5.4	7,268.1	470.9	563.1	-7,215.2
Spain	2,300.8	30.6	7,774.1	1,050.5	1,385.3	-7,878.4
Italy	3,427.0	45.6	9,109.3	1,437.0	1,891.9	-8,965.6
Canada	2,718.2	34.0	10,140.8	1,489.8	1,421.4	-10,299.8
Rep. of Korea	3,812.6	35.9	11,020.0	2,521.8	841.1	-10,534.4
France	3,114.5	70.5	11,471.2	1,898.5	2,674.1	-12,858.8
Netherland	2,397.5	31.2	10,891.6	3,845.3	1,189.4	-13,497.7
England	3,897.1	80.0	15,583.6	1,746.0	2,499.5	-15,852.0
Japan	3,871.4	65.6	20,451.8	1,483.2	1,495.4	-19,493.2
Germany	8,473.3	366.8	22,449.3	5,591.3	4,619.4	-23,819.8
USA	6,851.7	510.9	61,198.0	3,101.0	6,484.2	-63,420.6
Total	268,383.9	4,915.2	268,383.9	43,755.9	38,840.7	-77,681.4

Source: Authors' own calculations, based on WIOD

Table 2 Jobs generated by final goods trade and global production networks 2009 (in thousands)

	Final goods trade	Global production networks
Germany	30922.7	10577.5
USA	68049.7	10096.1
China	157711.9	9730.8
Netherland	13289.1	5066.0
France	14585.7	4643.1
England	19480.7	4325.5
Rep. of Korea	14832.6	3398.8
Italy	12536.3	3374.5
Belgium	5607.7	3137.7
Japan	24323.2	3044.2
Canada	12858.9	2945.3
Mexico	10371.7	2485.3
Spain	10074.9	2466.3
Taiwan, China	6926.9	2222.4
India	42979.2	1877.8
Poland	6741.7	1685.0
Czech	3851.2	1553.2
Austria	3517.4	1482.5
Sweden	3349.4	1398.8
Ireland	2857.0	1340.3
Russia	14930.7	1170.0
Hungary	2478.2	1136.8
Australia	8349.6	1039.4
Demark	2504.2	1009.1
Turkey	5203.3	968.8
Finland	2077.4	774.9
Indonesia	14128.4	761.3
Slovak	1715.6	727.6
Brazil	10353.9	677.4
Portugal	1920.6	576.3
Romania	2694.3	486.4
Greece	2012.2	470.7
Slovenia	569.0	220.3
Bulgaria	1347.6	197.6
Lithuania	634.2	172.1
Estonia	315.1	89.9
Latvia	323.3	75.1
Malta	164.1	57.6
Cyprus	178.2	49.6
Total	**536767.8**	**87511.8**

Source: Authors' own calculations, based on WIOD

5.2 Jobs from vertical specialization by skill level

An important feature of this analysis is that it enables us to look in more detail into the employment effect of each country's participation in GPN. Regarding the import content of exports, we find that in 2009, it led to the demand for about 44 million jobs within the 38 countries. Third-country intermediates trade generated labour demand of about 39 million jobs. And the export content of imports created demand for about 5 million jobs.

Using the data on "hours worked by skill type"[17] in the Social Economic Accounts, we find that on a global scale, vertical specialization contained significantly more medium-skill and low-skill labour content than high-skill. That is, of the jobs generated by vertical specialization in 2009, 13 per cent were high-skill, 44 per cent were medium-skill, and 43 per cent were low-skill. In 2009, the labour demand from vertical specialization in India, Indonesia, Cyprus, Australia and Japan has mostly been for low-skill workers, whereas in Ireland, China, Finland, and Sweden the import content of exports has demanded more high-skill workers compared to other countries. In fact, this result might very well contradict the Heckscher-Ohlin (H-O) trade theory because the theory would predict that developed countries would demand more low skilled labours in their exports, whereas developing countries would demand more high skilled labours in their exports. This contradiction will be an interesting point of departure for future research.

5.3 Changes in domestic and foreign labour demand

The WIOD has data over the period 1995–2009, so we can compute the employment *changes* generated by foreign trade over this period. Table 3 reports the change in employment generated by each of the five components of trade over the period 1995–2009. The analysis shows that most of the countries have increased their labour demand for each of the five components. Note that a negative figure in Table 3 does not necessarily imply that a particular component of foreign trade for a particular country has declined over the period 1995–2009. It is also possible that this particular component of trade has become less labour-intensive over the years. An extreme example is Japan, whose imports over time have led to reduced-demand for foreign employment (almost by 40 per cent between 1995 and 2009). This does not mean that Japan reduced its final goods imports by the same amount. Indeed, the Asian economic crisis in late 1990s has caused significant imports decline for Japan, but in addition to this effect, we may also speculate that Japan has been importing final goods that are increasingly less labour-intensive from 1995 to 2009. Japan's participation in GPN and the employment effects is another curious case that awaits further analysis.

[17] In the WIOD, skill-levels are defined on the basis of educational attainment levels (see Timmer, 2012). Although sector data on educational attainment levels is not accurate enough for some of the countries, the data can still provide us with an intuitive picture about skill-levels distributions across various sectors for each country.

Table 3: Change in employment in five components of foreign trade, 1995–2009 (in thousands)

	Domestic Labour		Foreign Labour			
	Exports	Export content of Imports	Imports	Import Content of Exports	Third Party imports in imports	Differences (Domestic - Foreign)
China	46,723.5	2,739.5	13,976.6	3,552.9	1,741.8	30,191.7
Japan	591.8	6.2	-14,022.8	285.6	-481.5	14,816.7
Netherland	371.3	1.5	-2,440.7	-837.1	233.2	3,417.3
India	8,249.6	69.1	6,123.8	1,135.4	328.9	730.6
Taiwan, China	666.8	14.4	-155.9	460.5	-32.8	409.5
Brazil	2,402.4	12.0	1,845.7	109.8	186.1	272.8
Bulgaria	370.0	1.2	204.1	42.1	77.2	47.8
Cyprus	-0.5	0.0	9.8	-4.7	11.4	-16.9
Malta	18.0	0.0	61.3	17.6	5.8	-66.7
Latvia	4.2	0.6	80.9	12.5	38.9	-127.5
Estonia	-24.4	0.1	77.0	28.3	22.8	-152.3
Slovenia	-0.9	0.2	142.7	53.6	47.6	-244.6
Demark	20.6	1.2	159.6	39.7	148.5	-326.0
Portugal	34.4	2.2	263.4	21.0	129.2	-377.0
Lithuania	-59.2	0.8	235.6	69.0	52.5	-415.4
Belgium	8.7	-2.9	600.2	-111.0	-39.0	-444.4
Finland	35.6	0.0	285.0	147.3	123.4	-520.1
Romania	344.9	5.1	720.7	128.1	231.8	-730.5
Italy	135.7	3.6	481.3	95.8	487.2	-733.4
Indonesia	191.2	4.6	979.9	20.8	-20.7	-784.3
Slovak	157.6	-1.5	511.6	311.2	202.1	-868.7
Austria	331.5	3.9	587.7	374.9	265.0	-892.1
Sweden	54.0	-0.3	770.3	260.5	145.9	-1,123.0
Greece	-25.9	0.4	1,063.5	39.6	177.7	-1,306.3
Hungary	338.0	4.6	794.2	586.5	313.3	-1,351.4
Turkey	194.1	4.3	1,750.9	186.3	296.1	-2,034.9
Ireland	147.8	1.4	1,442.7	507.5	245.7	-2,046.7
Czech	204.1	-3.1	1,246.2	742.3	362.1	-2,149.6
Poland	1,096.6	21.7	2,215.8	733.0	575.1	-2,405.6
Rep. of Korea	765.6	15.7	2,377.2	756.1	249.6	-2,601.6
Mexico	1,805.6	20.2	2,953.6	1,157.7	498.5	-2,784.0
Germany	2,985.6	107.9	2,242.3	2,666.7	985.9	-2,801.5
Australia	278.4	3.2	2,840.4	193.1	215.4	-2,967.3
Canada	-272.6	-8.0	3,227.1	85.4	515.0	-4,108.1
Spain	818.0	17.2	4,280.5	560.9	626.0	-4,632.2
France	13.8	-8.1	3,410.0	556.3	683.5	-4,644.1
England	-54.9	-3.4	5,565.5	257.4	550.7	-6,431.9
Russia	-2,051.6	-10.5	4,994.4	80.9	544.7	-7,682.2
USA	-263.9	-189.2	14,703.9	827.8	2,378.7	-18,363.5
Total	**66,605.7**	**2,835.9**	**66,605.7**	**15,959.5**	**13,123.6**	**-26,247.3**

Source: Authors' own calculations, based on WIOD.

At the aggregate level, for the panel of 39 countries, final goods trade (total of exports and imports) generated demand for 67 million jobs in 2009, a 25 per cent increase from the 1995 level. However, the increase in labour demand from GPN trade is much faster. The total import content of exports (vertical specialization) and total third-party intermediates trade generated an additional 16 million jobs (a 36 per cent increase from its 1995 level) and 13 million jobs (a 34 per cent increase from its 1995 level), respectively. Finally, the total export content of imports has added additional 3 million jobs, a 58 per cent increase from its 1995 level.

The relatively large employment increase related to GPN trade is consistent with existing research that has identified vertical specialization as the main driver of trade expansion since the late 1990s (Yi, 2003). The rapid increase in "processing trade" (Ma and Assche, 2010) since the 1990s is also reflected in the large increase in labour demand generated by the export content of imports. From the home country's perspective, if its imports contains large amount of its own exports, it means that this country is heavily involved in processing trade: the home country adds values through processing, and exports to other countries; other countries then make them into final products, and the home country imports them back (Stehrer et al., 2012).

For most countries in our sample, trade has generated more additional foreign jobs than domestic jobs between 1995 and 2009. Among the countries that have generated more additional domestic jobs than foreign jobs through trade, the top six are China, Japan, the Netherlands, India, Taiwan, and Brazil. Three of these – Japan, the Netherlands, and Taiwan – have achieved this large difference by reducing foreign labour demand, whereas the other three countries – which also happen to be three large developing economies – have achieved large difference by generating much more additional domestic employment than foreign employment as a result of their foreign trade. The countries at the bottom of the list in Table 3 are mostly developed countries except for Russia.

Did participation in GPN unambiguously create jobs for participants? Did it do so on a global scale? We find that in 2009, GPN trade demanded about 87.5 million jobs globally, which is additional 32 million jobs compared to the 1995 level. However, we do not know the counterfactual level of employment, that is, if the countries had *not* participated in GPN. If we assume no other trade-based employment would have been created in the absence of participation in GPN, then our calculations provide the answer to this question. In future research we will explore this issue of a counterfactual in more detail.

6 Conclusions and policy implications

In a vertically specialized world, value created by a country's foreign trade contains five components – direct exports, direct imports, import content of exports, export content of imports, and third-country intermediates trade. With the availability of World Input-Output Database (WIOD), we are able calculate the amount of employment associated with each of the five components, providing a comprehensive measure of the employment effects of international trade. The relation between trade and employment in a vertically specialized is no longer simple and straightforward as in the "old world" which assumes no trade in intermediates. However, we would also like to point out that the complication added onto the relation between trade and employment by the existence of GPN also potentially provides more policy instruments in using trade policies to influence employment outcomes.

Back to the employment matrix Λ in (10), traditional trade policies only focus on the diagonal elements, namely, final exports and imports. But in a vertically specialized world, trade policies should also consider the off-diagonal elements in the Λ matrix, namely, the import content of exports, the export content of imports, and third-party intermediates trade. In other words, policy designed to reduce domestic unemployment via foreign trade should also take into account the employment effect of the country's participation in GPN. In principle, holding everything else constant, jobs can be created by policies which would support substituting the import content of exports with domestic intermediates, and/or expanding the export content of imports while final exports and imports remain unchanged. But policies as such would have to depart from traditional industrial and trade policies and turn toward types of policies focusing more on industrial organizations and supply-chain managements. Nevertheless, we are not providing specific policy recommendations here; instead, we simply want to point out that there is a space for some new employment policy in a vertically specialized world.

The results shown in Tables 1 and 2 are aggregate results, but this method also gives results that are disaggregated to the sector level. For some sectors in some countries, most of its trade expansion might be absorbed by foreign labour, whereas for some other sectors, trade protection might create more unemployment than employment domestically. Employment policies should thus take into account sectoral variation in GPN participation. With the prevalence of international division of labour and product fragmentation, understanding trade related macro issues (such as employment, growth, income distribution etc.) in relation to GPN is extremely useful for both researchers and policy-makers. The existence of WIOD combined with regional input-output factor content method greatly facilitates this process. We hope this paper will be a useful starting point for future research on full spectrum of the employment effects of foreign trade in light of global production networks.

References

Bergstrand, J.; Egger, P. 2008. *The growth of FDI relative to trade: Measurement, determinants, and consequences of international trade flows in intermediates*, mimeo.

Chenery, H.B.; Watanabe, T. 1958. “International comparisons of the structure of production”, in *Econometrica*, Vol. 26, No. 4, pp. 487–521.

Escaith, H.; Lindenberg, N.; Miroudot, S. 2010. *International supply chains and trade elasticity in times of global crisis*, Staff Working Paper ERSD-2010-08 (Geneva, World Trade Organization (WTO)).

Gereffi, G. 1994. “The organzation of buyer-driven global commodity chains: How U.S. retailers shape overseas production networks”, in G. Gereffi and M. Korzeniewicz (eds.): *Commodity chains and global capitalism* (Westport, CT, Praeger).

Gibson, B. 2011. ‘Assessing the impact of trade on employment’ in M. Jensen, P. Ralf and J. Salazar-Xirinachs: *Trade and employment from myths to facts* (Geneva, ILO), pp. 61–124.

Hummels, D.; Ishii, J.; Yi, K.-M. 2001. “The nature and growth of vertical specialization in world trade”, in *Journal of International Economics* Vol. 54, No. 1, pp. 75–96.

Humphrey, J. 2004. *Upgrading in global value chains*, Working Paper No. 28, World Commission on the Social Dimension of Globalization (Geneva, ILO).

Jiang, X. 2013. “Trade expansion and employment generation: How mercantilist does China have to be”, in *International Review of Applied Economics* Vol. 27, No. 5, pp. 557–573.

—; Milberg, W. 2012. *Vertical specialization and industrial upgrading: A preliminary note*, Capturing the Gains Working Paper No. 10 (Manchester, University of Manchester).

Koopman, R.; Powers. W.; Wang, Z.; Wei, S.-J. 2010. *Give credit where credit is due: Tracing value added in global production chains*, NBER Working Paper No. 16426. (Cambridge, MA, National Bureau of Economic Research).

Kucera, D.; Milberg, W. 2003. “Trade and the loss of manufacturing jobs in the OECD: New factor content calculations for 1978–1995”, in *Review of World Economics*, Vol. 139, No. 4, pp. 601–624.

—. 2000. “Gender segregation and gender bias in manufacturing trade expansion: Revisiting the ‘Wood Asymmetry’” in *World Development*, Vol. 28, No. 7, pp. 1191–1210.

Los, B.; Marcel, T.; de Vries, G. 2012. *China and the world economy: A global value chain perspective on exports, incomes and jobs*, GGDC Working Paper GD-128 (Groningen, Growth and Development Centre).

Lydall, H. 1975. *Trade and employment: A study of the effects of trade expansion on employment in developing and developed countries* (Geneva, ILO).

Ma, A.C.; Van Assche, A. 2010. *The role of trade cost in global production networks: Evidence from China’s processing trade regime*, Policy Research Working Paper No. 5409 (Washington, DC, World Bank).

McGregor, P.G.; Swales, J.K.; Yin, Y. P. 1996. “A long-run interpretation of regional input-output analysis”, in *Journal of Regional Science,* Vol. 36, No. 3, pp. 479–501.

Meng, B.; Yamano, N.; Webb, C. 2011. *Application of factor decomposition techniques to vertical specialization measurements*, Discussion Paper No. 276 (Chiba, Institute of Developing Economies, Japan External Trade Organization).

Miller, R.E.; Blair, P.D. 2009. *Input-output analysis: Foundations and extensions* (Cambridge: Cambridge University Press).

Miroudot, S.; Ragoussis, A. 2009. *Vertical trade, trade costs, and FDI*, OECD Trade Policy Working Paper No. 89 (Paris, OECD).

Miroudot, S.; Rainer, L.; Ragoussis, A. 2009. *Trade in intermediate goods and services*. OECD Trade Policy Working Paper No. 93 (Paris, OECD).

Sachs, J.D.; Shatz, H.J.; Deardorff, A.; Hall, R.E. 1994. ‘Trade and jobs in US manufacturing; Comments and discussion’ in *Brookings Papers on Economic Activity*, Vol. 1994, No. 1, pp. 1–84.

Stehrer, R.; Foster, N.; de Vries, G. 2012. *Value added and factors in trade: A comprehensive approach*, wiiw Working Paper No. 80 (Vienna: The Vienna Institue for International Economics Studies).

Sturgeon, T.J.; Memedovic, O. 2010. *Mapping global value chains: Intermediate goods trade and structural change in the world economy*, Development Policy and Research Branch Working Paper No. 5 (Vienna: United Nations Industrial Development Organization (UNIDO)).

Timmer, M. 2012. *The world input-output database (WIOD): Contents, sources and methods*. World Input-Output Database, available at: http://www.wiod.org/.

Yi, K.-M. 2003. “Can vertical specialization explain the growth of world trade?” in *Journal of Political Economy*, Vol. 111, No. 1, pp. 52 –102.