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Measuring Bilateral Exports of Value Added

A Unified Framework

Bart Los and Marcel P. Timmer

11.1 Introduction

Which countries are most important in demanding value added of a country? This is a pressing question for policy makers seeking for example to (re)negotiate trade agreements or assessing the domestic consequences of foreign demand shocks. If trade in intermediate products would be absent, the answer to this question would be simple and could be derived from bilateral gross export statistics. However, with international fragmentation of production processes, trade flows need to be measured in value added terms as countries will be exporting and importing intermediates (Hummels, Ishii, and Yi 2001).¹ The main aim of this chapter is to offer an integrated discussion on measures of value added in *bilateral* trade flows. We provide a unified framework based on an application of the hypothetical extraction method in global input-output tables, along the lines of Los, Timmer, and

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1. Trade in value added measurement has quickly expanded and broadened into a wider set of so-called global value chain (GVC) measures. See Johnson (2017) for a general overview. By now, these statistics are part of the toolkit for trade policy analysis. For example, they are published on a regular basis by the OECD/WTO Trade in value added (TiVA) initiative and in the WITS (World Integrated Trade Solution) database.

de Vries (2016). We believe that this is helpful in cleaning up terminology, standardizing concepts, and more generally providing clear guidelines about which measure to use for what type of questions.

In particular, we show that the bilateral trade measures introduced by Johnson and Noguera (2012) (value added consumed abroad) and Los, Timmer, and de Vries (2016) (value added in exports) are special cases of a general class of VAX measures. We will therefore refer to these as VAX-C and VAX-D, respectively. In addition we suggest a novel third measure, VAX-P, which indicates the value added used abroad in the final stage of production. This is another relevant measure as it is at this final stage where demand shocks are transmitted to production and associated intermediates trade flows, as in Bems, Johnson, and Yi (2011, 2013). As for VAX-C, there can be flows of VAX-P between pairs of countries that do not directly trade with each other.

We show that all VAX measures can be derived with the method of hypothetical extraction in a general input-output model. In addition, the framework will also help to elucidate the relationship between aggregate and bilateral measures.² This is important as currently there are two alternative definitions of bilateral VAX-D: one suggested by Los, Timmer, and de Vries (2016) and another by Wang, Wei, and Zhu (2018). We will argue that the first is more suitable for trade analysis as it does not impose that the sum of VAX-D to all destinations is equal to VAX-D in aggregate exports. We show that the difference is small empirically (at current levels of international fragmentation of production processes) but outline the fundamental conceptual difference which potentially can cause major confusion for users.

The remainder of the chapter is organized as follows. We will lay out concepts and terminology through some simple examples in section 11.2. This is to develop intuition. The actual computational formulas are given in section 11.3. Empirical examples for a few large countries based on data from the World Input-Output Database are discussed in section 11.4.³ Section 11.5 defends our choice for a bilateral VAX-D measure. Section 11.6 concludes.

11.2 Concepts and Terminology

In this section we will lay out our concepts and terminology, and illustrate these with an example of a simple sequential production chain (a “snake”). The general insights do not depend on the example, however, and as shown

2. We use the term *aggregate exports* to refer to the total exports of a country, irrespective of the partner country. This is to be distinguished from *bilateral exports* that are for a specific destination.

3. A full annual time series (2000–2014) of bilateral measures for 43 countries has been made available to the research community, via <https://www.rug.nl/ggdc/valuechain/gvc-research/2018-nber>.

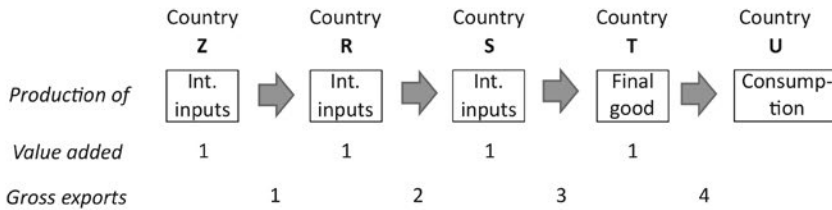


Figure 11.1. Example of sequential production chain

| | | Intermediate use | | | | | Final use | | | | | Total use |
|--------------|---|------------------|---|---|---|---|-----------|---|---|---|---|-----------|
| | | Z | R | S | T | U | Z | R | S | T | U | |
| Produced by | Z | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | R | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | S | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | T | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | U | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| value added | | 1 | 1 | 1 | 1 | 0 | | | | | | |
| gross output | | 1 | 2 | 3 | 4 | 0 | | | | | | |

Figure 11.2 Input-output table corresponding to figure 11.1

algebraically in section 11.3, they are generally applicable in any constellation of the production network.⁴

Figure 11.1 depicts a simple production process in which there are four stages of production, each taking place in a different country. We opt for the most simple constellation through which we can still illustrate our concepts. Country Z produces an intermediate input (from scratch), used by country R to produce intermediates, which are subsequently used by country S to produce an intermediate for country T. Country T is what we call the country-of-completion. This is the country where the final stage of production takes place. Country U is importing the final good from Country T and consumes it.⁵ In each stage of production 1 unit of value is added to the product, such that the price paid for the final product is 4.

In Figure 11.2 we show the input-output table that corresponds to this production chain. The intermediate use block has the very simple structure of a sequential production chain.⁶ Note that gross output of each product

4. It can consist of snakes, spiders, or any combination of these (see Baldwin and Venables 2013 for a discussion of the differences).

5. Throughout the paper we will refer to consumption, for ease of exposition. In the empirical analysis, we consider final use, which does not only include household and government consumption, but also private and public gross fixed capital formation and changes in inventories.

6. More formally, a snake is a production chain that can be represented (with suitable permutation) in the intermediate use matrix by a single non-main diagonal of positive transaction values and zeros elsewhere.

Table 11.1 Measures of bilateral exports

| | From R to | | | From S to | | From T to U |
|------------------------------------|-----------|---|---|-----------|---|----------------|
| | S | T | U | T | U | |
| Gross exports | 2 | 0 | 0 | 3 | 0 | 4 |
| Domestic value added exports (VAX) | | | | | | |
| for direct use (VAX-D) | 1 | 0 | 0 | 1 | 0 | 1 |
| for final stage production (VAX-P) | 0 | 1 | 0 | 1 | 0 | 0 |
| for consumption (VAX-C) | 0 | 0 | 1 | 0 | 1 | 1 |

Note: based on Figure 11.1.

(in the bottom row) is equal to its total use (indicated in the last column) as required to have a closed system such that use is equal to supply for all products.⁷ In the next section, we will use this IO table to discuss the complications arising from “loops.”

With this setup we next introduce the family of bilateral export measures. These are shown in table 11.1. We only report on those country pairs for which there is a non-zero export flow for at least one of the measures (so we do not report, for instance, on bilateral exports from U to any other country). We also do not report on Z, as this is not needed for making our main points. The numbers should be clear from the example, and can be checked using the information in table 11.1 with the formulas to be presented in section 11.3. The first row indicates the traditional gross flows. The next rows show three different variants of value added exports (VAX): for direct use (VAX-D), for final stage production (VAX-P) and for consumption (VAX-C).

Various alternative indices of bilateral VAX-D have been suggested, e.g., by Hummels, Ishii, and Yi (2001); Los, Timmer, and de Vries (2016); and Wang, Wei, and Zhu (2018). We prefer to use the one suggested by Los, Timmer, and de Vries (2016) as will be explained in section 11.5. VAX-D is equal to gross exports when all activities needed to produce the exported good are performed within the exporting country. The share of VAX-D in gross exports is declining in the amount of intermediates imported by the country in any domestic stage of production. For R, the share of VAX-D in gross exports is 0.5. Note that VAX-D includes value added in the export of intermediates (as in exports from S to T) as well as of final goods (as in exports from T to U).

Johnson and Noguera (2012) introduced the concept of VAX-C at both the aggregate and bilateral level. Johnson (2014) provides an overview of stylized facts. It is defined as the value added that is generated in a country but consumed abroad.⁸ We refer to it as VAX-C. Unlike VAX-C, VAX-D

7. The input-output tables presented throughout the paper are expressed in monetary units.

8. Johnson and Noguera (2012, 2017) refer to it as “value added absorbed abroad.” In the context of VAX-P and VAX-C, “absorbed by” is ambiguous (as it could be absorbed in the final product, or by the consumer) and we therefore say “consumed abroad” instead.

includes all value added that crosses the border, irrespective of where it is ultimately consumed. Considered for the aggregate set of other countries, it is therefore always at least as large as VAX-C, and strictly larger if some VAX-D is consumed domestically (as shown in Koopman, Wang, and Wei 2014). This is not true when considering bilateral flows, however. It is here that the conceptual difference between VAX-D and VAX-C is most visible. There can be a bilateral flow of VAX-C between a pair of countries without a direct flow of exports, as in the case of R to U, or S to U, as indicated in table 11.1.

This characteristic of VAX-C has major implications for its use in trade analysis. VAX-C is a popular measure and used for example by Aichele, Felbermayr, and Heiland (2014); Johnson and Noguera (2017); Kaplan, Kohl, and Martinez-Zarzoso (2018); and Brakman, Garretsen, and Kohl (2018) in studies of the effects of trade agreements. They relate bilateral VAX-C flows to trade agreements between the two countries involved, using a gravity equation framework. Using trade flows in value added terms rather than gross exports is needed indeed. Yet, such analyses should ideally be based on VAX-D rather than VAX-C flows.⁹ This can be explained by referring to the stylized production chain in figure 11.1. A reduction of trade barriers between R and S is commonly supposed to have positive effects on the bilateral value added exports between these two countries, which is captured by VAX-D. The effects of a trade agreement between R and U are less obvious, however. Such an agreement will not reduce trade barriers at borders that are crossed by R's exported value added, which are the borders between R and S, between S and T, and between T and U. The first order effect of a trade agreement between R and U on the value added exported from R to U is therefore expected to be nil. Trade barriers at other borders are likely to be much more relevant and should be modeled as well in the gravity setup, even when one is only interested in the effects of trade agreements on VAX-C.¹⁰

We introduce a third measure of VAX, namely VAX for final stage production (VAX-P). It is the domestic value added in exports that is used abroad in the production of a final good. This is another relevant measure, as it is at this final stage where consumption and investment demand shocks for specific products are transmitted to production and associated intermediates trade flows, as in Bems, Johnson, and Yi (2011, 2013), who studied the causes of the global trade collapse in 2008–2009. There might also be idiosyncratic shocks to the final-stage country, which will percolate to its trading partners further up the chain. Blanchard, Bown, and Johnson (2017), for example,

9. This might not be surprising, given the fact that VAX-C was the only value added based trade measure defined at the bilateral level for quite a while. More recently, Dhingra, Freeman, and Mavroeidi (2018), and Laget et al. (2018) studied trade policies using VAX-D measures. Unfortunately, they use the measure proposed by Wang, Wei, and Zhu (2018), about which we argue that it has an undesirable property (see section 11.5).

10. This point is also made in Noguera (2012).

| | | | Use by country-industries | | | | | | Final use by countries | | | Total use |
|----------------------------------|-----------|------------|---------------------------|-----|------------|-----------|------------|-----|-------------------------|--|--|-----------|
| | | | Country 1 | | | Country M | | | Country 1 ... Country M | | | |
| | | | Industry 1 | ... | Industry N | ... | Industry 1 | ... | Industry N | | | |
| Supply from country-industries | Country 1 | Industry 1 | | | | | | | | | | |
| | | ... | | | | | | | | | | |
| | | Industry N | | | | | | | | | | |
| | Country M | Industry 1 | | | | | | | | | | |
| | | ... | | | | | | | | | | |
| | | Industry N | | | | | | | | | | |
| Value added by labor and capital | | | | | | | | | | | | |
| Gross output | | | | | | | | | | | | |

Figure 11.3 The structure of a global input-output table

Note: Global IO tables do not have country detail for all countries in the world. Hence, Country M often refers to a region labeled “Rest of World.”

Source: Timmer et al. (2015).

analyze the relationships between tariffs on final products sold by specific countries and the origins of value added contained in these.

As a final comment, it should be noted that in principle an unlimited number of related measures could be introduced, only bounded by the number of stages in the chain. We view VAX-P as the most relevant, however (in addition to VAX-D and VAX-C), as it clearly delineates between trade in intermediate and in final products. After this stage there is only trade in final goods, and before this stage there is only trade in intermediates in the chain. As for VAX-C, there can be flows of VAX-P between a pair of countries without a flow of direct exports, as from R to T.

11.3 A Unified Framework for Bilateral Value Added Export Measures

11.3.1 Preliminaries and Notation

In this section, we show how the three indicators of bilateral exports of domestic value added can be computed if a global input-output table is available. The general structure of such a table is given by figure 11.3.

In what follows, we will assume that the countries in a global input-output table can be grouped into three groups: (i) the country (or group of countries) for which we want to compute VAX-indicators, indicated by r ; (ii) the country (or group of countries) that acts as the destination of the VAX, indicated by s ; and (iii) the other countries in the world, indicated by t . In matrix notation, the input-output structure of figure 11.3 can in this context be represented by a limited number of matrices and vectors:¹¹

11. Matrices are indicated by bold capitals, column vectors by bold lowercases, and scalars by italics. Primes denote transposition, and hats stand for diagonal matrices.

$$\mathbf{Z} \equiv \begin{bmatrix} \mathbf{Z}_{rr} & \mathbf{Z}_{rs} & \mathbf{Z}_{rt} \\ \mathbf{Z}_{sr} & \mathbf{Z}_{ss} & \mathbf{Z}_{st} \\ \mathbf{Z}_{tr} & \mathbf{Z}_{ts} & \mathbf{Z}_{tt} \end{bmatrix}; \mathbf{Y} \equiv \begin{bmatrix} \mathbf{Y}_{rr} & \mathbf{Y}_{rs} & \mathbf{Y}_{rt} \\ \mathbf{Y}_{sr} & \mathbf{Y}_{ss} & \mathbf{Y}_{st} \\ \mathbf{Y}_{tr} & \mathbf{Y}_{ts} & \mathbf{Y}_{tt} \end{bmatrix}; \mathbf{w} \equiv \begin{bmatrix} \mathbf{w}_r \\ \mathbf{w}_s \\ \mathbf{w}_t \end{bmatrix}; \mathbf{x} \equiv \begin{bmatrix} \mathbf{x}_r \\ \mathbf{x}_s \\ \mathbf{x}_t \end{bmatrix}.$$

There are M countries, each with N industries. \mathbf{Z} is the $NM \times NM$ matrix of which the elements indicate the transaction values of sales among industries in the accounting period, usually a year. The rows refer to the supplying industries, the columns to using industries. Both transactions within a country (in the diagonal submatrices) and cross-border transactions (in the off-diagonal submatrices) are included in this matrix. It should be noted that the submatrices generally do not have the same dimensions. In order to avoid aggregation biases (Morimoto 1970), all industry and country detail should be retained in the computations. If r is a single country, \mathbf{Z}^{rr} has N rows and columns. If s is a group of M_s countries, \mathbf{Z}^{ss} has NM_s rows and columns.

\mathbf{Y} is the rectangular matrix of which the elements give the transaction values of sales by industries to final users. Like in \mathbf{Z} , both domestic and international transactions are contained in this matrix. Since we treat all final use categories (household consumption, gross fixed capital formation, etc.) in the same way, \mathbf{Y} contains M columns (one column for each country). Since all industries in all countries can sell to final users, the number of rows is NM . The dimensions of the submatrices vary, depending on the numbers of countries included in r , s , and t .

Value added in each of the industries in each country is contained in the NM -vector \mathbf{w} , and gross output levels in the NM -vector \mathbf{x} . The well-known input-output identities apply. The sum of intermediate sales and sales to final users (both summed over countries of destination) equals gross output, $\mathbf{x} = \mathbf{Z}\mathbf{i} + \mathbf{Y}\mathbf{i}$, in which \mathbf{i} denotes a summation vector (of appropriate length) containing ones; the sum of purchases of intermediate inputs and payments for production factors (value added) also add up to these values, $\mathbf{x} = \mathbf{i}'\mathbf{Z} + \mathbf{w}$.

The production requirements *per unit of output* are given by the $NM \times NM$ matrix \mathbf{A} (for intermediate inputs) and the NM -vector \mathbf{v} (for factor payments):

$$(1) \quad \mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1} = \begin{bmatrix} \mathbf{A}_{rr} & \mathbf{A}_{rs} & \mathbf{A}_{rt} \\ \mathbf{A}_{sr} & \mathbf{A}_{ss} & \mathbf{A}_{st} \\ \mathbf{A}_{tr} & \mathbf{A}_{ts} & \mathbf{A}_{tt} \end{bmatrix}; \mathbf{v} = \hat{\mathbf{x}}^{-1}\mathbf{w} \equiv \begin{bmatrix} \mathbf{v}_r \\ \mathbf{v}_s \\ \mathbf{v}_t \end{bmatrix}.$$

Country r 's GDP can now be obtained by linking value added generation to the final demand levels in \mathbf{Y} by means of Leontief's demand-driven input-output model:

$$(2) \quad GDP_r = \mathbf{v}_r'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}\mathbf{i}$$

in which $\tilde{\mathbf{v}}_r$ denotes the NM -vector that is identical to \mathbf{v} as defined in (1) with respect to the part \mathbf{v}_r , but in which all other elements are set equal to zero.¹² The matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse. The industry that is producing the final product often uses its own production factors, as well as intermediate inputs from first-tier suppliers. These can be located in the same country, but also elsewhere. First-tier suppliers generate value added themselves, but might also use intermediate inputs for their activities. The same goes for second-tier suppliers producing these, and so on.¹³

In their comment on Koopman, Wang, and Wei (2014), Los, Timmer, and de Vries (2016) showed that using a particular type of the “Hypothetical Extraction Method” (HEM) as pioneered by Paelinck, de Caemel, and Joseph Degueldre (1965) and Strassert (1968) can be used to derive VAX-D.¹⁴ The main part of Los, Timmer, and de Vries (2016) dealt with the aggregate case, in which domestic value added in the exports of country r to all other countries is considered at once. They also proposed a bilateral extension, to which we will turn now.

11.3.2 The Hypothetical Extraction Method (HEM)

HEM-applications usually “extract” industries or countries from input-output structures by setting corresponding parts of matrices that are involved in the computations to zero. Equation (2) is then recomputed for the modified matrices: the result is called the hypothetical GDP level. The difference between the actual and the hypothetical GDP levels is a measure of the importance of the extracted industry. In computing VAX-D, we do not extract entire industries (or countries) from the system, but just some transactions. If we are interested in VAX-D between r and s , we set all elements of \mathbf{A}_{rs} and \mathbf{Y}_{rs} to zero, assuming that s does not use any imports of intermediate and final products from r . One might think of this as a situation in which s sets import tariffs on goods from r that are prohibitively high. We indicate the modified matrices with a $*$:

$$(3) \quad \mathbf{A}_r^{*s} \equiv \begin{bmatrix} \mathbf{A}_{rr} & \mathbf{0} & \mathbf{A}_{rt} \\ \mathbf{A}_{sr} & \mathbf{A}_{ss} & \mathbf{A}_{st} \\ \mathbf{A}_{tr} & \mathbf{A}_{ts} & \mathbf{A}_{tt} \end{bmatrix}; \mathbf{Y}_r^{*s} \equiv \begin{bmatrix} \mathbf{Y}_{rr} & \mathbf{0} & \mathbf{Y}_{rt} \\ \mathbf{Y}_{sr} & \mathbf{Y}_{ss} & \mathbf{Y}_{st} \\ \mathbf{Y}_{tr} & \mathbf{Y}_{ts} & \mathbf{Y}_{tt} \end{bmatrix}.$$

Next, we compute the GDP level in r for the situation in which these matrices would have represented the global production structure and final demand levels:

12. If the vector \mathbf{v} would be used instead, we would obtain world GDP rather than GDP of r .

13. See, e.g., the appendix of Los, Timmer, and de Vries (2015) for a more extensive exposition.

14. See Miller and Lahr (2001) for a comprehensive overview of HEM-based input-output analyses, and Dietzenbacher, van der Linden, and Steenge (1993) for an application involving multiple countries.

$$(4) \quad GDP_r^{*s} = \hat{v}'_r(\mathbf{I} - \mathbf{A}_r^{*s})^{-1}\mathbf{Y}_r^{*s}\mathbf{i}.$$

The value added of r contained in direct exports to s is now given by the difference between r 's actual GDP level and its hypothetical GDP level:

$$(5) \quad VAXD_{rs} = GDP_r - GDP_r^{*s}.$$

We would like to emphasize that GDP_r^{*s} should not be seen as the GDP level that would result if exports to s would be prohibitive. In a general setting with more flexible production and demand functions, substitution effects will occur. As a consequence, the global production structure and final demand levels will change and the global production structure after the tariff shock will not be represented by \mathbf{A}_r^{*s} and \mathbf{Y}_r^{*s} . $VAXD_{rs}$ should therefore be regarded as an upper limit to the loss in GDP_r and is most meaningful if compared to other scenarios of extracted transactions. Put otherwise, it is a measure of the relative importance of country s for exports of value added by r .¹⁵

We now show how VAX-P can be computed in a similar framework by setting elements of one or more matrices in (2) to zero (see below for a simpler computational formula). VAX-P is the amount of value added used abroad for final production. If we hypothetically extract all final demand for output produced by industries in country s , we have

$$(6) \quad \mathbf{Y}_r^{\#s} \equiv \begin{bmatrix} \mathbf{Y}_{rr} & \mathbf{Y}_{rs} & \mathbf{Y}_{rt} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{Y}_{tr} & \mathbf{Y}_{ts} & \mathbf{Y}_{tt} \end{bmatrix}$$

and hypothetical GDP in r is given by

$$(7) \quad GDP_r^{\#s} = \hat{v}'_r(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}_r^{\#s}\mathbf{i}.$$

For VAX-P, we now have the expression

$$(8) \quad VAXP_{rs} = GDP_r - GDP_r^{\#s}.$$

Johnson and Noguera's (2012) VAX-C indicator can also easily be considered within this HEM-approach (see below for a simpler computational formula for VAX-C). If we hypothetically extract all demand by final users in country s , we have

$$(9) \quad \mathbf{Y}_r^{\&s} \equiv \begin{bmatrix} \mathbf{Y}_{rr} & \mathbf{0} & \mathbf{Y}_{rt} \\ \mathbf{Y}_{sr} & \mathbf{0} & \mathbf{Y}_{st} \\ \mathbf{Y}_{tr} & \mathbf{0} & \mathbf{Y}_{tt} \end{bmatrix}.$$

15. See, for example, Chen et al. (2018), who measure regional GDP-shares "at risk" to Brexit using this HEM-approach, but argue that substitution effects will most probably lead to smaller actual GDP losses.

The hypothetical GDP-level associated with this extraction reads

$$(10) \quad GDP_r^{\&s} = \tilde{v}'_r(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}_r^{\&s}\mathbf{i}$$

and we obtain the following expression for VAX-C:

$$(11) \quad VAX_{rs} = GDP_r - GDP_r^{\&s}.$$

This completes the discussion of the unified framework in which the three measures of bilateral exports of value added can be presented. The aggregate indicator of VAX-D can be computed by means of slightly modified versions of (3), (4) and (5). \mathbf{A}_r^{*st} and \mathbf{Y}_r^{*st} are obtained by simultaneously setting \mathbf{A}_{rs} , \mathbf{A}_{rt} , \mathbf{Y}_{rs} and \mathbf{Y}_{rt} equal to zero, after which they are substituted for \mathbf{A}_r^{*s} and \mathbf{Y}_r^{*s} in (4). The result (GDP_r^{*st}) is then subtracted from actual GDP, as in (5). The aggregate counterpart of VAX-P is computed by not only setting the row associated with final demand for output from country s but also the row for output from country t equal to zero in (6). Finally, setting both columns for consumption in s and in t in (9) to zero, (10) and (11) yield the aggregate VAX-C.

11.3.3 Simplified Expressions for Calculation of VAX

So far, we derived VAX measures using the HEM approach. We did this to stress the relationships between the three VAX indicators. Yet, VAX-P and VAX-C can also be computed in a simpler way given the fact that it only involves the tracing of parts of the final demand matrix. Following the exposition by Los, Timmer, and de Vries (2015), VAX-P from r to s can be expressed as a simple multiplication with demand for products finalized in s (by any country in the world, including r):

$$(12) \quad VAXP_{rs} = \tilde{v}'_r(\mathbf{I} - \mathbf{A})^{-1} [\mathbf{Y}_{sr} \ \mathbf{Y}_{ss} \ \mathbf{Y}_{st}] \mathbf{i}.$$

Likewise, Johnson and Noguera's (2012) bilateral VAX-C from r to s is usually written as:

$$(13) \quad VAXC_{rs} = \tilde{v}'_r(\mathbf{I} - \mathbf{A})^{-1} \begin{bmatrix} \mathbf{Y}_{rs} \\ \mathbf{Y}_{ss} \\ \mathbf{Y}_{ts} \end{bmatrix},$$

involving only the demand of s for products finalized in any country, including country r itself.

11.4 Empirical Illustrations

In this section we provide some empirical illustrations of the measures we introduced using the 2016 release of the World Input-Output Database (Timmer et al. 2015). We study the VAX of some major countries in the world (China, Japan, Germany, United Kingdom, and United States), as

Table 11.2 Various aggregate VAX measures, 2014

| | VAX-D/GX | VAX-C/VAX-D | VAX-P/VAX-D |
|----------------|----------|-------------|-------------|
| China | 82.4% | 96.3% | 47.1% |
| United States | 87.0% | 92.1% | 61.1% |
| Germany | 70.2% | 95.4% | 53.8% |
| Japan | 74.7% | 98.4% | 56.8% |
| United Kingdom | 77.4% | 97.9% | 63.1% |
| Australia | 83.9% | 99.1% | 83.7% |
| Brazil | 77.1% | 99.4% | 74.6% |

Note: Authors' calculations based on WIOD, 2016 release.

well as some global suppliers of raw materials (Australia and Brazil).¹⁶ We show that bilateral measures can vary widely across the various measures and provide some intuitive interpretation. All results are for the year 2014 and values are expressed in million US\$. For background, we first provide a comparison of aggregate measures of GX, VAX-D, VAX-P and VAX-C in table 11.2. Tables 11A.1 to 11A.7 provide for each country the bilateral GX and VAX flows to each of the 42 partner countries (and the rest-of-the-world region), the share of each partner in total flows as well as the ranking based on these shares. We highlight some interesting results.

11.4.1 VAX-D Compared to GX

Column 1 in table 11.2 confirms the finding of Koopman, Wang, and Wei (2014) that aggregate VAX-D is smaller than gross exports (GX). Ratios vary from 70 percent for Germany to 87 percent for the United States, reflecting the difference in the import content of their exports as stressed by Hummels, Ishii, and Yi (2001). As argued by Koopman, Wang, and Wei (2012), these ratios are likely to be overestimations if firm heterogeneity is such that more export-intensive firms have lower VAX-D ratios. They showed that this was the case for China, using data that distinguish between processing exports and other firms.¹⁷

Appendix tables 11A.1 through 11A.7 provide information on the bilateral VAX-D values. In general, the rankings of export destinations are similar for the gross exports and the VAX-D measures. This is not surprising given the nature of the available data. Information on input requirements generally does not vary across export partners. As a consequence, the representation of production technologies of exporting industries is not destination specific, and the WIOD data are no exception. Hence, the VAX-D to GX ratio

16. The measures for all 43 countries included in the 2016 release of WIOD have been made available at the WIOD website (www.wiod.org/gvc#nber).

17. The OECD Trade in Value Added database makes this distinction for China and Mexico.

for a given product is the same across all partners. The variation in results across bilateral partners thus comes from variation in the product mixes of exports bundles toward the various destinations. For example, Canada and Mexico become less important as export partners for the United States in terms of VAX-D compared to gross exports. This is because the US exports to these countries is skewed toward products with a low VAX-D ratio. On the other hand, China becomes more important for Brazil as an export destination in terms of VAX-D, because Brazilian exports to China mainly consist of raw materials, which have a very high VAX-D ratio.

11.4.2 VAX-C Compared to VAX-D

VAX-D includes all value added that crosses the border, irrespective of where it is ultimately consumed. From an aggregate perspective, it is therefore always at least as large as VAX-C, as VAX-C only considers value added that is also ultimately consumed abroad (Johnson and Noguera 2012). Koopman, Wang, and Wei (2014) showed that the empirical differences are small, and we confirm this in the second column of table 11.2. This is not true when considering bilateral flows, however, and it is here that the conceptual and empirical differences are clearly visible. First of all, bilateral VAX-C can be higher than GX, and we find many examples of this, in particular in exports toward major consumer markets such as China, Japan, and the United States. Countries export directly toward these destinations, but also indirectly through other countries (as also found by Johnson and Noguera 2012).

Second, for individual countries, the importance of various destinations do change compared to VAX-D. For example, South Korea and Taiwan are less important for Japan as consumers of its value added than as direct export markets, while the United States is more important as a consumer than as a direct export destination. Similarly, Canada and Mexico are less important for the United States, and continental Europe is less important for Germany as consumers than as direct export destination. These findings confirm the well-documented existence of regional production networks (see, e.g., Los, Timmer, and de Vries 2015).

11.4.3 VAX-P Compared to VAX-D

The last column of table 11.2 provides a comparison of aggregate VAX-P with VAX-D. It reveals interesting variation across countries. VAX-P must be lower than VAX-D by definition, as it only captures exports of value added that are used in final production abroad. Hence VAX-P will not include exports of final goods, and the ratio of VAX-P to VAX-D will thus be mainly influenced by the share of intermediate products (including natural resources) in a country's exports. Not surprisingly, the ratio varies from 47 percent for China, which exports relatively little intermediates, to as much as 84 percent for Australia, which mainly exports primary intermediates.

The bilateral measures shown in the appendix tables reveal additional

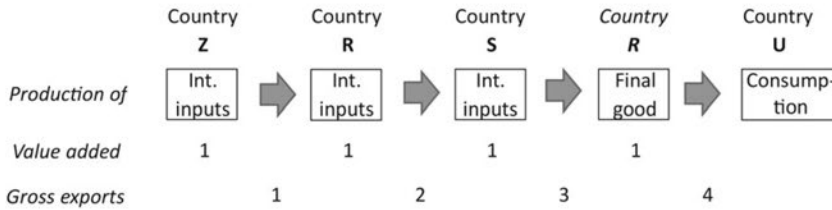


Figure 11.4 Example of production chain (with loop)

patterns. The share of VAX-P going to China is typically (much) higher than the share of VAX-D or VAX-C going there, confirming its important role as a final assembler using intermediates produced elsewhere. For example, 15.3 percent of direct VAX from Japan goes to China, vs. 19.6 percent of VAX-P. Similarly, 5.7 percent of US VAX-D goes to China, while 8.1 percent of VAX-P. Interestingly, Chinese VAX-P goes more to less advanced countries (such as India, Indonesia, and Mexico) and South Korea (relative to VAX-D or VAX-C shares). Yet the United States and Japan are still the largest receivers of Chinese VAX-P.

11.5 Which Bilateral VAX-D Measure to Use?

The *aggregate* concept of value added exports for direct use (VAX-D) has been introduced by Hummels, Ishii, and Yi (2001), and Koopman, Wang, and Wei (2012), and there is unanimous agreement on how to measure it.¹⁸ This is not true for the *bilateral* VAX-D measure. Various alternative indices have been suggested, including those by Hummels, Ishii, and Yi (2001); Los, Timmer, and de Vries (2016); and Wang, Wei, and Zhu (2018). We prefer to use the one suggested by Los, Timmer, and de Vries (2016) because it is the only one which allows for a situation in which the sum of the bilateral measures across all destinations is not equal to the aggregate measure. This is so in cases in which an exporting country is involved in a specific type of “feedback loop” (Miller 1966). This situation arises if a country is importing its own value added (embodied in intermediate inputs) from one country to produce its exports to another country.¹⁹

An example is easily created by replacing country T in figure 11.1 by country R, see figure 11.4. In this case, R is importing its own value added

18. In fact, Hummels, Ishii, and Yi (2001) suggested the complement to VAX-D: the import content of exports, and referred to it as VS (“vertical specialization”). Koopman, Wang, and Wei (2012) showed that VAX-D is equal to gross exports minus VS (see also Los, Timmer, and de Vries, 2016).

19. Value added exported to the final stage, or the final consumer, can obviously never be exported by the exporting country again. Hence bilateral VAX always sums to aggregate VAX in the case of VAX-P and VAX-C.

| | | Intermediate use | | | | Final use | | | | Total Use |
|-------------|--------------|------------------|---|---|---|-----------|---|---|---|-----------|
| | | Z | R | S | U | Z | R | S | U | |
| Produced by | Z | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | R | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 6 |
| | S | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | U | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | value added | 1 | 2 | 1 | 0 | | | | | |
| | gross output | 1 | 6 | 3 | 0 | | | | | |

Figure 11.5 Input-output table corresponding to figure 11.4

Table 11.3 Measures of bilateral exports

| | From R to | | | From S to | | |
|------------------------------------|-----------|---|-----|-----------|---|-----|
| | S | U | All | R | U | All |
| Gross exports | 2 | 4 | 6 | 3 | 0 | 3 |
| Domestic value added exports (VAX) | | | | | | |
| for direct use (VAX-D) | 1 | 2 | 2 | 1 | 0 | 1 |
| for final stage production (VAX-P) | 0 | 0 | 0 | 1 | 0 | 1 |
| for consumption (VAX-C) | 0 | 2 | 2 | 0 | 1 | 1 |

Note: based on Figure 11.4

that was generated in an earlier stage when producing its exports to S. The corresponding input-output table is shown in figure 11.5. Mathematically, an input-output table has a loop if none of all possible permutations of the intermediate use matrix yields a *triangular matrix*, defined as a matrix with exclusively zeros below the main diagonal. Such permutations must involve simultaneous changes in the order of the columns and corresponding rows, otherwise the equality of row (use) and column sum (supply) is violated.²⁰ In the example of figure 11.4, it is clear that there is a loop, as S delivers intermediates to R and vice versa, hence there is always a positive value below the diagonal block, irrespective of how the countries are ordered in the table.

In table 11.3 we report on the bilateral VAX measures, as well as the aggregate (in the columns headed by All). Again, we only report on pairs of countries for which there is a non-zero flow for at least one of the VAX measures. The measures for S are not surprising and basically repeat those for T in the snake example presented in section 11.2 (see table 11.1). R is the country of interest. It carries out two stages of production, and exports

20. Chenery and Watanabe (1958) discuss triangularization of input-output matrices in order to make matrix manipulations computationally less cumbersome (which at that time was of course an important topic). Simpson and Tsukui (1956) discuss the economic meaning of (block)triangular input-output tables.

directly to two countries: S and U. Its gross exports are 6, while it generates only 2 units of value added in the chain. This is clear from VAX-C: both units are ultimately consumed in U and the sum of the bilateral measures is equal to the aggregate measure. This is also true for VAX-P, which in this case is not so insightful, as R is the country of completion so VAX-P is zero by definition, for all bilateral pairs as well as in the aggregate sense.

The interesting case arises for VAX-D. R exports 1 unit of value added to S, and R exports 2 units of its value added to U: the value added in the second stage of the chain and in the fourth stage. Yet, the aggregate VAX-D is also 2. This is obvious as R adds only 2 units of value added to the chain. We now have a case where the sum of the bilateral measures is higher (3) than the aggregate one (2). The reason is that R exports the value added it generates in the second stage of the chain twice: first directly to S, and again embodied in exports to U. We therefore refer to the difference between the sum of the bilateral VAX-Ds and the aggregate VAX-D as the *double count of domestic value added in summing bilateral measures*.

In a recently revised paper, Wang, Wei, and Zhu (2018)—WWZ from hereon—provide an alternative measure of bilateral VAX-D, which rules out this type of double counts by design. The authors wish to develop an accounting system in which the overall value added (GDP) of a country is assigned to (bilateral) export flows in a mutually exclusive way. From that perspective, it is only natural to impose an aggregation restriction upfront. But there is a cost involved regarding the measurement of trade relationships. In the WWZ accounting framework, the value added in exports from R to U would be only 1 unit, not 2. In that way the bilateral measures sum to the aggregate. This might be justified when accounting for GDP, but it is counterintuitive from a trade perspective. If U would no longer demand the final good from R, value added in R will decline by 2 units, as both stages of production are no longer needed. The hypothetical extraction method introduced in the previous section provides a mathematical underpinning for this intuition.

One could argue (as in WWZ) that by tracing the exports and contributions of *different industries in a country* this double counting would be eliminated. Assume that the first task carried out by R is done in industry R1 (which exports to S), and the second task by industry R2 (which exports to U). When considering the exports to U one could say that the exports from R2 contain 1 unit of value added by R2. Yet, it remains true that the aggregate exports from R contain 2 units of R's value added. Having more detailed input-output tables will thus not resolve this as long as one wishes to study aggregate exports of a country, rather than of separate industries in a country.

To be clear, we do not claim that the WWZ decomposition is mathematically “wrong.” As long as the accounting restrictions are obeyed, an accounting framework is correct. But we do claim that the decomposition

Table 11.4 VAX-D double counts, selected countries, 2014

| | VAX-D double count |
|----------------|--------------------|
| Germany | 1.8% |
| China | 0.8% |
| United States | 0.7% |
| Japan | 0.3% |
| United Kingdom | 0.3% |
| Australia | 0.1% |
| Brazil | 0.1% |

Note: VAX-D double count is the sum of the bilateral VAX-D to all partners minus the aggregate VAX-D. It is expressed as a percentage of aggregate VAX-D. Authors' calculations based on WIOD 2016 release.

is essentially arbitrary as one can come up with many alternatives that are equally valid. Without an economic model, it is impossible to defend any choice among these. This point is also made by Nagengast and Stehrer (2016), and they propose to identify the trade flow in which value added is actually recorded for the first time in international trade statistics to allocate value added. Actually, there is a deep and fundamental problem in trying to allocate value added to gross trade flows. Note that the elements in an IO table are summations of transactions within a particular time frame, typically a year. It does not record the sequence of the transactions. This is important to emphasize, because it implies that it is generally impossible to retrieve the underlying production chain, except in very simple cases such as a snake (as stressed by Nomaler and Verspagen, 2014). If loops are present, many different networks can underlie the same IO table. Hence, it is impossible to allocate value added to gross flows, and any “solution” is essentially arbitrary.

Fortunately in empirical terms, the double counts have (so far) been minor. Table 11.4 provides information on the double count in VAX-D. It is defined as the sum of the bilateral VAX-D to all export partners minus the aggregate VAX-D, expressed as a percentage of the latter. It follows that this term is not large, and typically less than 1 percent. The maximum (1.8 percent) is found for the case of Germany, signifying that this country has sizeable back-and-forth trade that is bigger than for other countries. The lowest double counts are found for Australia and Brazil, countries that specialize in exporting natural resources. The value added generated in mining for exports is generally not returning to these countries in the form of intermediate inputs.

11.6 Concluding Remarks

In this chapter we provided an integrated discussion of three useful measures of value added exports at the bilateral level: VAX-D as introduced by

Los, Timmer, and de Vries (2016); VAX-C as introduced by Johnson and Noguera (2012); and VAX-P, a novel measure that indicates the value added used abroad in the final stage of production. We showed that the measures have different interpretations, while they belong to the same class of indicators. All can be derived with the method of hypothetical extraction in a general input-output model. In addition we show that the sum of bilateral measures for VAX-D might differ from the corresponding aggregate measure (as opposed to VAX-P and VAX-C). This happens if the country of interest is involved in feedback loops within production networks, i.e., if the production of exports of a country requires imported intermediates to which the country contributed value added in upstream stages of production. This is an inherent feature of intricate production networks. We illustrate all measures with some numerical examples using the World Input-Output Database and show that they do not differ only conceptually but also empirically.

Many extensions are possible, in particular using economic indicators other than value added, such as labor income or hours worked (see, e.g., Chen et al. 2018). Progress will depend on the further availability of new and improved data sources. The popularity of VAX measures in the policy arena is not (yet) properly matched by the quality of the available data, as many gaps and inconsistencies in primary data collection remain. Harmonizing national and international data collection efforts and institutionalizing their production in regular statistical programs is a major challenge, see, e.g., Landefeld (2015). Ongoing efforts in the international statistical community toward this goal are therefore very welcome and deserve full support.

Appendix

Table 11A.1 Bilateral exports by China, 2014

| | Million US\$ | | | | Shares in total | | | | Ranking of countries | | | | | |
|--------------------|--------------|---------|---------|---------|-----------------|-------|-------|-------|----------------------|----|-------|----|-------|-------|
| | VAX-D | | VAX-P | | GX | VAX-D | | VAX-P | VAX-C | GX | VAX-D | | VAX-P | VAX-C |
| | GX | | | | | | | | | | | | | |
| United States | 347,311 | 280,320 | 123,637 | 320,289 | 14.3% | 14.0% | 13.1% | 16.7% | | 1 | 1 | 1 | 1 | 1 |
| Japan | 172,861 | 140,285 | 55,341 | 137,386 | 7.1% | 7.0% | 5.9% | 7.1% | | 2 | 2 | 2 | 2 | 2 |
| South Korea | 101,924 | 81,605 | 46,955 | 56,392 | 4.2% | 4.1% | 5.0% | 2.9% | | 3 | 3 | 3 | 3 | 5 |
| Germany | 88,465 | 72,334 | 35,614 | 71,375 | 3.6% | 3.6% | 3.8% | 3.7% | | 4 | 4 | 4 | 4 | 3 |
| Russian Federation | 65,198 | 56,474 | 14,834 | 62,062 | 2.7% | 2.8% | 1.6% | 3.2% | | 5 | 5 | 5 | 13 | 4 |
| United Kingdom | 51,850 | 42,270 | 21,216 | 49,968 | 2.1% | 2.1% | 2.3% | 2.6% | | 6 | 6 | 6 | 8 | 6 |
| Canada | 49,636 | 40,763 | 21,667 | 43,000 | 2.0% | 2.0% | 2.3% | 2.2% | | 7 | 7 | 7 | 7 | 8 |
| Australia | 48,459 | 39,568 | 19,714 | 43,198 | 2.0% | 2.0% | 2.1% | 2.2% | | 8 | 8 | 8 | 10 | 7 |
| India | 44,869 | 36,269 | 24,407 | 39,846 | 1.8% | 1.8% | 2.6% | 2.1% | | 9 | 9 | 9 | 5 | 9 |
| Taiwan | 43,622 | 34,210 | 14,413 | 20,401 | 1.8% | 1.7% | 1.5% | 1.1% | | 10 | 11 | 14 | 16 | 16 |
| Netherlands | 42,640 | 34,215 | 13,863 | 26,891 | 1.8% | 1.7% | 1.5% | 1.4% | | 11 | 10 | 15 | 13 | 13 |
| France | 41,291 | 34,061 | 21,759 | 38,267 | 1.7% | 1.7% | 2.3% | 2.0% | | 12 | 12 | 6 | 10 | 10 |
| Brazil | 38,988 | 31,703 | 19,966 | 36,926 | 1.6% | 1.6% | 2.1% | 1.9% | | 13 | 13 | 9 | 11 | 11 |
| Mexico | 38,330 | 30,554 | 17,932 | 25,082 | 1.6% | 1.5% | 1.9% | 1.3% | | 14 | 14 | 12 | 15 | 15 |
| Indonesia | 34,969 | 28,644 | 19,225 | 29,300 | 1.4% | 1.4% | 2.0% | 1.5% | | 15 | 15 | 11 | 12 | 12 |
| Italy | 28,865 | 23,873 | 13,690 | 25,699 | 1.2% | 1.2% | 1.5% | 1.3% | | 16 | 16 | 16 | 14 | 14 |
| Turkey | 23,149 | 18,558 | 10,112 | 18,765 | 1.0% | 0.9% | 1.1% | 1.0% | | 17 | 17 | 17 | 18 | 18 |
| Spain | 21,496 | 17,849 | 9,595 | 19,998 | 0.9% | 0.9% | 1.0% | 1.0% | | 18 | 18 | 18 | 17 | 17 |
| Poland | 14,316 | 11,541 | 5,868 | 11,771 | 0.6% | 0.6% | 0.6% | 0.6% | | 19 | 19 | 20 | 19 | 19 |
| Belgium | 11,804 | 9,862 | 6,303 | 9,490 | 0.5% | 0.5% | 0.7% | 0.5% | | 20 | 20 | 19 | 20 | 20 |
| Sweden | 11,173 | 9,445 | 5,849 | 9,005 | 0.5% | 0.5% | 0.6% | 0.5% | | 21 | 21 | 21 | 21 | 21 |
| Czech Republic | 8,898 | 6,855 | 3,952 | 4,800 | 0.4% | 0.3% | 0.4% | 0.2% | | 22 | 22 | 22 | 22 | 27 |

Table 11A.2 **Bilateral exports by United States, 2014**

| | Million US\$ | | | | | | Shares in total | | | | Ranking of countries | | | |
|----------------|--------------|---------|---------|---------|-------|-------|-----------------|-------|-------|-------|----------------------|-------|-------|-------|
| | GX | | VAX-D | | VAX-P | | GX | VAX-D | VAX-P | VAX-C | GX | VAX-D | VAX-P | VAX-C |
| | | | | | | | | | | | | | | |
| Canada | 291,930 | 242,458 | 120,217 | 185,228 | 15.1% | 14.5% | 11.7% | 12.0% | 1 | 1 | 1 | 1 | 1 | 1 |
| Mexico | 178,587 | 146,127 | 91,872 | 99,465 | 9.3% | 8.7% | 9.0% | 6.4% | 2 | 2 | 2 | 2 | 2 | 3 |
| China | 112,051 | 95,421 | 83,364 | 120,552 | 5.8% | 5.7% | 8.1% | 7.8% | 3 | 3 | 3 | 3 | 3 | 2 |
| Germany | 79,939 | 70,486 | 46,817 | 69,805 | 4.1% | 4.2% | 4.6% | 4.5% | 4 | 4 | 4 | 4 | 4 | 5 |
| United Kingdom | 73,796 | 62,847 | 35,678 | 69,873 | 3.8% | 3.7% | 3.5% | 4.5% | 5 | 5 | 5 | 5 | 7 | 4 |
| Japan | 63,598 | 54,682 | 40,820 | 61,562 | 3.3% | 3.3% | 4.0% | 4.0% | 6 | 6 | 7 | 5 | 5 | 6 |
| Ireland | 61,756 | 58,371 | 29,031 | 16,962 | 3.2% | 3.5% | 2.8% | 1.1% | 7 | 7 | 6 | 8 | 8 | 15 |
| France | 57,720 | 49,924 | 37,565 | 49,212 | 3.0% | 3.0% | 3.7% | 3.2% | 8 | 8 | 8 | 6 | 6 | 7 |
| Netherlands | 47,920 | 42,699 | 20,478 | 26,914 | 2.5% | 2.5% | 2.0% | 1.7% | 9 | 9 | 9 | 11 | 11 | 11 |
| South Korea | 43,887 | 38,138 | 24,817 | 32,619 | 2.3% | 2.3% | 2.4% | 2.1% | 10 | 10 | 10 | 10 | 10 | 9 |
| Brazil | 40,464 | 33,572 | 25,773 | 36,374 | 2.1% | 2.0% | 2.5% | 2.4% | 11 | 11 | 11 | 9 | 9 | 8 |
| Belgium | 29,823 | 26,553 | 15,603 | 19,119 | 1.5% | 1.6% | 1.5% | 1.2% | 12 | 12 | 12 | 13 | 13 | 13 |
| Australia | 26,813 | 23,109 | 13,636 | 27,004 | 1.4% | 1.4% | 1.3% | 1.7% | 13 | 13 | 13 | 15 | 15 | 10 |
| Luxembourg | 20,862 | 19,896 | 7,786 | 2,130 | 1.1% | 1.2% | 0.8% | 0.1% | 14 | 14 | 14 | 18 | 18 | 32 |
| Italy | 19,655 | 17,071 | 16,581 | 22,286 | 1.0% | 1.0% | 1.6% | 1.4% | 15 | 15 | 15 | 12 | 12 | 12 |
| Taiwan | 16,415 | 13,934 | 7,661 | 10,924 | 0.9% | 0.8% | 0.7% | 0.7% | 16 | 16 | 17 | 20 | 20 | 20 |
| India | 16,233 | 13,937 | 14,511 | 18,889 | 0.8% | 0.8% | 1.4% | 1.2% | 17 | 17 | 16 | 14 | 14 | 14 |
| Sweden | 13,598 | 12,437 | 7,675 | 12,559 | 0.7% | 0.7% | 0.7% | 0.8% | 18 | 18 | 18 | 19 | 19 | 17 |
| Switzerland | 13,415 | 11,797 | 9,671 | 12,484 | 0.7% | 0.7% | 0.9% | 0.8% | 19 | 19 | 19 | 16 | 16 | 19 |
| Spain | 10,955 | 9,312 | 9,049 | 13,821 | 0.6% | 0.6% | 0.9% | 0.9% | 20 | 20 | 20 | 17 | 17 | 16 |
| Turkey | 8,302 | 6,855 | 6,944 | 9,032 | 0.4% | 0.4% | 0.7% | 0.6% | 21 | 21 | 21 | 21 | 21 | 21 |

| | | | | | | | | | | | | |
|--------------------|-----------|-----------|-----------|-----------|-------|-------|-------|-------|----|----|----|----|
| Russian Federation | 7,081 | 5,811 | 4,984 | 12,557 | 0.4% | 0.3% | 0.5% | 0.8% | 22 | 23 | 24 | 18 |
| Denmark | 6,837 | 6,209 | 5,103 | 5,223 | 0.4% | 0.4% | 0.5% | 0.3% | 23 | 22 | 23 | 27 |
| Norway | 6,564 | 5,726 | 4,271 | 6,797 | 0.3% | 0.3% | 0.4% | 0.4% | 24 | 24 | 25 | 23 |
| Finland | 6,197 | 5,612 | 3,917 | 5,314 | 0.3% | 0.3% | 0.4% | 0.3% | 25 | 25 | 27 | 26 |
| Indonesia | 5,864 | 5,069 | 6,458 | 8,331 | 0.3% | 0.3% | 0.6% | 0.5% | 26 | 26 | 22 | 22 |
| Poland | 4,602 | 3,999 | 4,189 | 6,351 | 0.2% | 0.2% | 0.4% | 0.4% | 27 | 28 | 26 | 24 |
| Austria | 4,581 | 4,031 | 3,834 | 5,504 | 0.2% | 0.2% | 0.4% | 0.4% | 28 | 27 | 28 | 25 |
| Hungary | 3,402 | 3,093 | 2,582 | 2,523 | 0.2% | 0.2% | 0.3% | 0.2% | 29 | 29 | 29 | 30 |
| Czech Republic | 2,746 | 2,439 | 2,570 | 2,985 | 0.1% | 0.1% | 0.3% | 0.2% | 30 | 30 | 30 | 29 |
| Greece | 2,274 | 2,062 | 1,931 | 3,084 | 0.1% | 0.1% | 0.2% | 0.2% | 31 | 31 | 31 | 28 |
| Portugal | 1,566 | 1,383 | 1,595 | 2,429 | 0.1% | 0.1% | 0.2% | 0.2% | 32 | 32 | 32 | 31 |
| Romania | 1,223 | 1,042 | 1,376 | 2,000 | 0.1% | 0.1% | 0.1% | 0.1% | 33 | 33 | 33 | 33 |
| Slovak Republic | 763 | 687 | 1,111 | 1,159 | 0.0% | 0.0% | 0.1% | 0.1% | 34 | 34 | 34 | 34 |
| Bulgaria | 546 | 484 | 526 | 829 | 0.0% | 0.0% | 0.1% | 0.1% | 35 | 35 | 35 | 35 |
| Croatia | 480 | 437 | 436 | 625 | 0.0% | 0.0% | 0.0% | 0.0% | 36 | 36 | 37 | 37 |
| Lithuania | 435 | 368 | 269 | 659 | 0.0% | 0.0% | 0.0% | 0.0% | 37 | 37 | 39 | 36 |
| Slovenia | 372 | 327 | 327 | 596 | 0.0% | 0.0% | 0.0% | 0.0% | 38 | 38 | 38 | 38 |
| Malta | 356 | 313 | 491 | 285 | 0.0% | 0.0% | 0.0% | 0.0% | 39 | 39 | 36 | 42 |
| Estonia | 252 | 221 | 227 | 360 | 0.0% | 0.0% | 0.0% | 0.0% | 40 | 40 | 40 | 40 |
| Latvia | 233 | 207 | 213 | 394 | 0.0% | 0.0% | 0.0% | 0.0% | 41 | 41 | 41 | 39 |
| Cyprus | 146 | 130 | 181 | 341 | 0.0% | 0.0% | 0.0% | 0.0% | 42 | 42 | 42 | 41 |
| Rest of world | 642,853 | 577,983 | 312,213 | 559,590 | 33.4% | 34.5% | 30.5% | 36.2% | | | | |
| Sum of bilaterals | 1,927,091 | 1,677,256 | 1,024,353 | 1,544,752 | 67% | 66% | 70% | 64% | | | | |
| Aggregate | 1,927,091 | 1,666,117 | 1,024,353 | 1,544,752 | | | | | | | | |

Note: Authors' calculations based on WIOD, 2016 release.

Table 11A.3 **Bilateral exports by Germany, 2014**

| | Million US\$ | | | | | | Shares in total | | | Ranking of countries | | | | |
|--------------------|--------------|--------|--------|-------|-------|---------|-----------------|-------|-------|----------------------|----|-------|-------|-------|
| | GX | | | VAX-D | | | GX | VAX-D | VAX-P | VAX-C | GX | VAX-D | VAX-P | VAX-C |
| | GX | VAX-D | VAX-P | VAX-D | VAX-P | VAX-C | | | | | | | | |
| United States | 135,642 | 95,970 | 58,466 | 8.1% | 8.1% | 117,597 | 8.1% | 8.1% | 9.2% | 10.4% | 1 | 1 | 1 | 1 |
| France | 133,788 | 92,097 | 49,683 | 8.0% | 7.8% | 82,206 | 8.0% | 7.8% | 7.8% | 7.3% | 2 | 2 | 3 | 3 |
| China | 122,900 | 87,554 | 50,447 | 7.3% | 7.4% | 97,226 | 7.3% | 7.4% | 7.9% | 8.6% | 3 | 3 | 2 | 2 |
| United Kingdom | 103,347 | 73,161 | 39,573 | 6.1% | 6.2% | 74,075 | 6.1% | 6.2% | 6.2% | 6.6% | 4 | 4 | 4 | 4 |
| Italy | 84,740 | 58,590 | 33,124 | 5.0% | 5.0% | 49,916 | 5.0% | 5.0% | 5.2% | 4.4% | 5 | 5 | 5 | 5 |
| Austria | 77,551 | 52,540 | 21,284 | 4.6% | 4.4% | 35,208 | 4.6% | 4.4% | 3.4% | 3.1% | 6 | 6 | 6 | 8 |
| Netherlands | 72,853 | 48,837 | 19,555 | 4.3% | 4.1% | 32,708 | 4.3% | 4.1% | 3.1% | 2.9% | 7 | 7 | 9 | 9 |
| Switzerland | 63,955 | 45,823 | 20,935 | 3.8% | 3.9% | 35,731 | 3.8% | 3.9% | 3.3% | 3.2% | 8 | 8 | 7 | 7 |
| Poland | 61,604 | 41,328 | 20,485 | 3.7% | 3.5% | 31,549 | 3.7% | 3.5% | 3.2% | 2.8% | 9 | 9 | 8 | 11 |
| Spain | 50,542 | 35,337 | 19,104 | 3.0% | 3.0% | 32,109 | 3.0% | 3.0% | 3.0% | 2.9% | 10 | 10 | 10 | 10 |
| Russian Federation | 49,265 | 33,299 | 17,645 | 2.9% | 2.8% | 36,857 | 2.9% | 2.8% | 2.8% | 3.3% | 11 | 11 | 11 | 6 |
| Czech Republic | 42,855 | 29,056 | 14,061 | 2.5% | 2.5% | 15,467 | 2.5% | 2.5% | 2.2% | 1.4% | 12 | 12 | 12 | 17 |
| Belgium | 41,918 | 28,491 | 14,032 | 2.5% | 2.4% | 19,838 | 2.5% | 2.4% | 2.2% | 1.8% | 13 | 13 | 13 | 14 |
| Sweden | 32,584 | 22,950 | 10,117 | 1.9% | 1.9% | 20,040 | 1.9% | 1.9% | 1.6% | 1.8% | 14 | 14 | 16 | 13 |
| Turkey | 28,860 | 19,362 | 10,744 | 1.7% | 1.6% | 18,239 | 1.7% | 1.6% | 1.7% | 1.6% | 15 | 15 | 15 | 15 |
| Hungary | 27,183 | 19,047 | 10,099 | 1.6% | 1.6% | 8,425 | 1.6% | 1.6% | 1.6% | 0.7% | 16 | 16 | 17 | 27 |
| South Korea | 25,415 | 17,721 | 9,823 | 1.5% | 1.5% | 16,690 | 1.5% | 1.5% | 1.5% | 1.5% | 17 | 17 | 18 | 16 |
| Japan | 24,757 | 17,315 | 12,309 | 1.5% | 1.5% | 22,324 | 1.5% | 1.5% | 1.9% | 2.0% | 18 | 18 | 14 | 12 |
| Denmark | 24,165 | 16,554 | 9,784 | 1.4% | 1.4% | 11,677 | 1.4% | 1.4% | 1.5% | 1.0% | 19 | 19 | 19 | 21 |
| Brazil | 17,775 | 12,327 | 9,248 | 1.1% | 1.0% | 15,288 | 1.1% | 1.0% | 1.5% | 1.4% | 20 | 20 | 20 | 18 |
| Canada | 17,148 | 12,039 | 7,501 | 1.0% | 1.0% | 14,709 | 1.0% | 1.0% | 1.2% | 1.3% | 21 | 21 | 22 | 19 |

| | | | | | | | | | | | | | |
|-------------------|-----------|-----------|---------|-----------|-------|-------|-------|-------|-------|----|----|----|----|
| Finland | 15,078 | 10,670 | 5,867 | 8,688 | 0.9% | 0.9% | 0.9% | 0.9% | 0.8% | 22 | 22 | 25 | 25 |
| Mexico | 14,849 | 10,388 | 7,519 | 10,197 | 0.9% | 0.9% | 0.9% | 1.2% | 0.9% | 23 | 23 | 21 | 23 |
| Slovak Republic | 14,645 | 10,062 | 5,918 | 5,840 | 0.9% | 0.9% | 0.9% | 0.9% | 0.5% | 24 | 24 | 24 | 31 |
| Romania | 13,071 | 9,083 | 5,177 | 8,676 | 0.8% | 0.8% | 0.8% | 0.8% | 0.8% | 25 | 25 | 26 | 26 |
| India | 13,025 | 8,964 | 7,302 | 11,778 | 0.8% | 0.8% | 0.8% | 1.1% | 1.0% | 26 | 26 | 23 | 20 |
| Norway | 12,835 | 8,880 | 4,694 | 9,832 | 0.8% | 0.8% | 0.8% | 0.7% | 0.9% | 27 | 27 | 28 | 24 |
| Australia | 12,143 | 8,540 | 4,795 | 11,568 | 0.7% | 0.7% | 0.7% | 0.8% | 1.0% | 28 | 28 | 27 | 22 |
| Taiwan | 10,385 | 7,129 | 3,086 | 6,073 | 0.6% | 0.6% | 0.6% | 0.5% | 0.5% | 29 | 30 | 31 | 30 |
| Luxembourg | 10,284 | 7,548 | 2,671 | 3,816 | 0.6% | 0.6% | 0.6% | 0.4% | 0.3% | 30 | 29 | 33 | 34 |
| Portugal | 9,998 | 6,895 | 3,358 | 6,489 | 0.6% | 0.6% | 0.6% | 0.5% | 0.6% | 31 | 32 | 30 | 28 |
| Ireland | 9,475 | 7,077 | 4,238 | 5,174 | 0.6% | 0.6% | 0.6% | 0.7% | 0.5% | 32 | 31 | 29 | 32 |
| Greece | 7,710 | 5,514 | 1,975 | 6,266 | 0.5% | 0.5% | 0.5% | 0.3% | 0.6% | 33 | 33 | 34 | 29 |
| Slovenia | 4,664 | 3,232 | 1,416 | 2,506 | 0.3% | 0.3% | 0.3% | 0.2% | 0.2% | 34 | 34 | 35 | 36 |
| Indonesia | 4,215 | 2,916 | 2,820 | 4,492 | 0.3% | 0.3% | 0.2% | 0.4% | 0.4% | 35 | 35 | 32 | 33 |
| Bulgaria | 4,150 | 2,852 | 1,303 | 2,877 | 0.2% | 0.2% | 0.2% | 0.2% | 0.3% | 36 | 36 | 36 | 35 |
| Croatia | 3,231 | 2,268 | 1,138 | 2,369 | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 37 | 37 | 37 | 37 |
| Lithuania | 2,752 | 1,882 | 705 | 1,888 | 0.2% | 0.2% | 0.2% | 0.1% | 0.2% | 38 | 38 | 38 | 38 |
| Estonia | 2,139 | 1,427 | 652 | 1,166 | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 39 | 39 | 39 | 39 |
| Latvia | 1,396 | 964 | 459 | 1,085 | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 40 | 40 | 40 | 40 |
| Cyprus | 924 | 668 | 231 | 735 | 0.1% | 0.1% | 0.1% | 0.0% | 0.1% | 41 | 41 | 42 | 41 |
| Malta | 442 | 320 | 246 | 307 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 42 | 42 | 41 | 42 |
| Rest of world | 275,991 | 204,172 | 111,575 | 226,516 | 17.3% | 17.3% | 17.3% | 17.6% | 20.1% | | | | |
| Sum of bilaterals | 1,682,253 | 1,180,849 | 635,165 | 1,126,218 | 83% | 83% | 83% | 82% | 80% | | | | |
| Aggregate | 1,682,253 | 1,159,581 | 635,165 | 1,126,218 | | | | | | | | | |

Note: Authors' calculations based on WIOD, 2016 release.

| | | | | | | | | | | | | | |
|-------------------|---------|---------|---------|---------|-------|-------|-------|-------|----|----|----|----|----|
| Poland | 2,017 | 1,497 | 1,097 | 2,219 | 0.2% | 0.2% | 0.3% | 0.4% | 22 | 22 | 22 | 22 | 21 |
| Sweden | 1,524 | 1,152 | 738 | 1,695 | 0.2% | 0.2% | 0.2% | 0.3% | 23 | 23 | 25 | 22 | 22 |
| Norway | 1,476 | 1,071 | 598 | 1,412 | 0.2% | 0.2% | 0.2% | 0.2% | 24 | 24 | 27 | 23 | 23 |
| Czech Republic | 1,396 | 1,041 | 873 | 911 | 0.2% | 0.2% | 0.3% | 0.2% | 25 | 25 | 23 | 26 | 26 |
| Austria | 1,245 | 904 | 646 | 1,260 | 0.2% | 0.1% | 0.2% | 0.2% | 26 | 26 | 26 | 25 | 25 |
| Hungary | 1,146 | 873 | 773 | 532 | 0.1% | 0.1% | 0.2% | 0.1% | 27 | 27 | 24 | 30 | 30 |
| Finland | 546 | 409 | 432 | 647 | 0.1% | 0.1% | 0.1% | 0.1% | 28 | 28 | 30 | 28 | 28 |
| Denmark | 512 | 403 | 552 | 694 | 0.1% | 0.1% | 0.2% | 0.1% | 29 | 29 | 28 | 27 | 27 |
| Slovak Republic | 367 | 277 | 495 | 367 | 0.0% | 0.0% | 0.1% | 0.1% | 30 | 30 | 29 | 33 | 33 |
| Portugal | 342 | 256 | 310 | 482 | 0.0% | 0.0% | 0.1% | 0.1% | 31 | 31 | 32 | 31 | 31 |
| Luxembourg | 325 | 274 | 192 | 267 | 0.0% | 0.0% | 0.1% | 0.0% | 32 | 31 | 34 | 34 | 34 |
| Greece | 241 | 183 | 200 | 585 | 0.0% | 0.0% | 0.1% | 0.1% | 33 | 33 | 33 | 29 | 29 |
| Romania | 233 | 168 | 320 | 465 | 0.0% | 0.0% | 0.1% | 0.1% | 34 | 34 | 31 | 32 | 32 |
| Cyprus | 150 | 115 | 21 | 158 | 0.0% | 0.0% | 0.0% | 0.0% | 35 | 35 | 42 | 37 | 37 |
| Estonia | 128 | 95 | 58 | 134 | 0.0% | 0.0% | 0.0% | 0.0% | 36 | 36 | 37 | 38 | 38 |
| Slovenia | 101 | 74 | 84 | 162 | 0.0% | 0.0% | 0.0% | 0.0% | 37 | 37 | 36 | 36 | 36 |
| Bulgaria | 84 | 62 | 103 | 180 | 0.0% | 0.0% | 0.0% | 0.0% | 38 | 38 | 35 | 35 | 35 |
| Malta | 41 | 29 | 36 | 48 | 0.0% | 0.0% | 0.0% | 0.0% | 39 | 39 | 41 | 42 | 42 |
| Lithuania | 33 | 25 | 57 | 116 | 0.0% | 0.0% | 0.0% | 0.0% | 40 | 40 | 39 | 39 | 39 |
| Croatia | 27 | 21 | 57 | 114 | 0.0% | 0.0% | 0.0% | 0.0% | 41 | 41 | 41 | 40 | 40 |
| Latvia | 25 | 18 | 36 | 68 | 0.0% | 0.0% | 0.0% | 0.0% | 42 | 42 | 40 | 41 | 41 |
| Rest of world | 305,935 | 241,127 | 107,149 | 224,819 | 37.4% | 39.5% | 30.9% | 37.4% | | | | | |
| Sum of bilaterals | 817,514 | 610,362 | 346,832 | 600,551 | 63% | 60% | 69% | 63% | | | | | |
| Aggregate | 817,514 | 608,320 | 346,832 | 600,551 | | | | | | | | | |

Note: Authors' calculations based on WIOD, 2016 release.

Table 11A.5 **Bilateral exports by United Kingdom, 2014**

| | Million US\$ | | | | | | Shares in total | | | Ranking of countries | | | | | |
|--------------------|--------------|--------|--------|--------|-------|-------|-----------------|-------|-------|----------------------|----|-------|-------|-------|----|
| | GX | | | VAX | | | GX | VAX-D | VAX-P | VAX-C | GX | VAX-D | VAX-P | VAX-C | |
| | GX | VAX-D | VAX-P | VAX-D | VAX-P | VAX-C | | | | | | | | | |
| United States | 85,559 | 64,519 | 47,428 | 77,249 | 11.4% | 11.1% | 12.9% | 13.6% | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Germany | 54,147 | 40,702 | 25,403 | 36,615 | 7.2% | 7.0% | 6.9% | 6.4% | 2 | 2 | 3 | 3 | 2 | 3 | 2 |
| France | 46,573 | 36,845 | 25,954 | 34,209 | 6.2% | 6.3% | 7.1% | 6.0% | 3 | 3 | 2 | 3 | 2 | 3 | 3 |
| Ireland | 34,477 | 27,275 | 13,478 | 14,828 | 4.6% | 4.7% | 3.7% | 2.6% | 4 | 4 | 5 | 4 | 5 | 6 | 6 |
| China | 27,405 | 19,194 | 18,140 | 29,480 | 3.6% | 3.3% | 4.9% | 5.2% | 5 | 6 | 4 | 4 | 4 | 4 | 4 |
| Luxembourg | 23,757 | 20,654 | 8,153 | 2,404 | 3.2% | 3.6% | 2.2% | 0.4% | 6 | 5 | 8 | 5 | 8 | 29 | 29 |
| Netherlands | 23,602 | 17,874 | 8,065 | 12,956 | 3.1% | 3.1% | 2.2% | 2.3% | 7 | 7 | 10 | 7 | 10 | 8 | 8 |
| Italy | 21,798 | 17,132 | 11,863 | 17,953 | 2.9% | 2.9% | 3.2% | 3.2% | 8 | 8 | 6 | 6 | 6 | 5 | 5 |
| Belgium | 21,045 | 16,017 | 8,138 | 11,526 | 2.8% | 2.8% | 2.2% | 2.0% | 9 | 9 | 9 | 9 | 9 | 11 | 11 |
| Switzerland | 19,449 | 15,218 | 7,844 | 13,332 | 2.6% | 2.6% | 2.1% | 2.3% | 10 | 10 | 12 | 10 | 12 | 7 | 7 |
| Canada | 17,523 | 13,282 | 9,360 | 12,365 | 2.3% | 2.3% | 2.5% | 2.2% | 11 | 11 | 7 | 11 | 7 | 10 | 10 |
| Russian Federation | 14,236 | 10,309 | 3,625 | 12,742 | 1.9% | 1.8% | 1.0% | 2.2% | 12 | 12 | 20 | 12 | 20 | 9 | 9 |
| Spain | 12,959 | 9,666 | 5,975 | 10,234 | 1.7% | 1.7% | 1.6% | 1.8% | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| Sweden | 11,769 | 9,048 | 4,627 | 7,796 | 1.6% | 1.6% | 1.3% | 1.4% | 14 | 14 | 17 | 14 | 17 | 15 | 15 |
| Norway | 11,426 | 8,671 | 5,017 | 7,679 | 1.5% | 1.5% | 1.4% | 1.3% | 15 | 15 | 16 | 15 | 16 | 16 | 16 |
| Japan | 9,919 | 7,414 | 8,036 | 11,280 | 1.3% | 1.3% | 2.2% | 2.0% | 16 | 16 | 11 | 16 | 11 | 12 | 12 |
| South Korea | 9,694 | 7,405 | 5,808 | 7,148 | 1.3% | 1.3% | 1.6% | 1.3% | 17 | 17 | 14 | 17 | 14 | 17 | 17 |
| Australia | 8,990 | 6,920 | 3,998 | 8,393 | 1.2% | 1.2% | 1.1% | 1.5% | 18 | 18 | 19 | 18 | 19 | 14 | 14 |
| Denmark | 8,101 | 6,271 | 4,354 | 4,900 | 1.1% | 1.1% | 1.2% | 0.9% | 19 | 19 | 18 | 19 | 18 | 21 | 21 |
| India | 7,260 | 4,781 | 5,528 | 6,261 | 1.0% | 0.8% | 1.5% | 1.1% | 20 | 21 | 15 | 20 | 15 | 18 | 18 |
| Ireland | 7,153 | 5,509 | 3,281 | 5,880 | 1.0% | 0.9% | 0.9% | 1.0% | 21 | 20 | 22 | 21 | 22 | 20 | 20 |

| | | | | | | | | | | | | |
|-------------------|---------|---------|---------|---------|-------|-------|-------|-------|----|----|----|----|
| Turkey | 6,082 | 4,262 | 3,042 | 4,662 | 0.8% | 0.7% | 0.8% | 0.8% | 22 | 22 | 23 | 22 |
| Brazil | 5,091 | 3,838 | 3,439 | 5,885 | 0.7% | 0.7% | 0.9% | 1.0% | 23 | 23 | 21 | 19 |
| Finland | 3,784 | 2,940 | 1,957 | 2,810 | 0.5% | 0.5% | 0.5% | 0.5% | 24 | 24 | 26 | 25 |
| Austria | 3,486 | 2,658 | 2,061 | 3,342 | 0.5% | 0.5% | 0.6% | 0.6% | 25 | 25 | 25 | 24 |
| Czech Republic | 3,060 | 2,313 | 1,654 | 2,051 | 0.4% | 0.4% | 0.5% | 0.4% | 26 | 27 | 27 | 30 |
| Portugal | 3,050 | 2,372 | 1,433 | 2,606 | 0.4% | 0.4% | 0.4% | 0.5% | 27 | 26 | 28 | 26 |
| Mexico | 2,784 | 2,134 | 2,616 | 3,705 | 0.4% | 0.4% | 0.7% | 0.7% | 28 | 28 | 24 | 23 |
| Greece | 2,627 | 2,097 | 1,131 | 2,588 | 0.3% | 0.4% | 0.3% | 0.5% | 29 | 29 | 33 | 27 |
| Taiwan | 2,228 | 1,705 | 1,403 | 2,453 | 0.3% | 0.3% | 0.4% | 0.4% | 30 | 31 | 30 | 28 |
| Hungary | 2,122 | 1,657 | 1,249 | 1,339 | 0.3% | 0.3% | 0.3% | 0.2% | 31 | 32 | 31 | 33 |
| Malta | 1,983 | 1,717 | 1,175 | 653 | 0.3% | 0.3% | 0.3% | 0.1% | 32 | 30 | 32 | 37 |
| Romania | 1,567 | 1,204 | 988 | 1,547 | 0.2% | 0.2% | 0.3% | 0.3% | 33 | 33 | 34 | 32 |
| Cyprus | 1,080 | 853 | 303 | 836 | 0.1% | 0.1% | 0.1% | 0.1% | 34 | 34 | 37 | 34 |
| Indonesia | 972 | 722 | 1,415 | 1,993 | 0.1% | 0.1% | 0.4% | 0.4% | 35 | 35 | 29 | 31 |
| Slovak Republic | 810 | 605 | 608 | 730 | 0.1% | 0.1% | 0.2% | 0.1% | 36 | 36 | 35 | 35 |
| Bulgaria | 754 | 577 | 349 | 676 | 0.1% | 0.1% | 0.1% | 0.1% | 37 | 37 | 36 | 36 |
| Lithuania | 544 | 409 | 191 | 499 | 0.1% | 0.1% | 0.1% | 0.1% | 38 | 39 | 41 | 39 |
| Croatia | 521 | 420 | 294 | 519 | 0.1% | 0.1% | 0.1% | 0.1% | 39 | 38 | 38 | 38 |
| Estonia | 476 | 364 | 177 | 393 | 0.1% | 0.1% | 0.0% | 0.1% | 40 | 40 | 42 | 41 |
| Latvia | 465 | 359 | 194 | 416 | 0.1% | 0.1% | 0.1% | 0.1% | 41 | 41 | 40 | 40 |
| Slovenia | 421 | 315 | 225 | 376 | 0.1% | 0.1% | 0.1% | 0.1% | 42 | 42 | 39 | 42 |
| Rest of world | 230,852 | 183,150 | 107,091 | 184,102 | 30.7% | 31.5% | 29.2% | 32.3% | | | | |
| Sum of bilaterals | 751,599 | 581,373 | 367,067 | 569,411 | 69% | 68% | 71% | 68% | | | | |
| Aggregate | 751,599 | 579,453 | 367,067 | 569,411 | | | | | | | | |

Note: Authors' calculations based on WIOD, 2016 release.

Table 11A.6 **Bilateral exports by Australia, 2014**

| | Million US\$ | | | | | | Shares in total | | | | Ranking of countries | | | |
|----------------|--------------|--------|--------|--------|-------|-------|-----------------|-------|-------|-------|----------------------|-------|-------|-------|
| | GX | | VAX-D | | VAX-P | | GX | VAX-D | VAX-P | VAX-C | GX | VAX-D | VAX-P | VAX-C |
| | | | | | | | | | | | | | | |
| China | 76,645 | 64,395 | 59,484 | 59,182 | 26.7% | 26.7% | 26.7% | 26.7% | 29.5% | 24.8% | 1 | 1 | 1 | 1 |
| Japan | 46,272 | 39,248 | 30,752 | 32,570 | 16.1% | 16.1% | 16.1% | 16.3% | 15.3% | 13.6% | 2 | 2 | 2 | 2 |
| South Korea | 16,058 | 13,436 | 9,498 | 8,734 | 5.6% | 5.6% | 5.6% | 5.6% | 4.7% | 3.7% | 3 | 3 | 4 | 4 |
| Taiwan | 11,409 | 9,636 | 5,196 | 4,717 | 4.0% | 4.0% | 4.0% | 4.0% | 2.6% | 2.0% | 4 | 4 | 6 | 7 |
| United States | 10,161 | 8,294 | 9,546 | 17,430 | 3.5% | 3.5% | 3.5% | 3.4% | 4.7% | 7.3% | 5 | 5 | 3 | 3 |
| India | 7,844 | 6,305 | 6,625 | 6,661 | 2.7% | 2.7% | 2.7% | 2.6% | 3.3% | 2.8% | 6 | 6 | 5 | 5 |
| Indonesia | 6,361 | 5,294 | 5,010 | 5,962 | 2.2% | 2.2% | 2.2% | 2.2% | 2.5% | 2.5% | 7 | 7 | 7 | 6 |
| United Kingdom | 3,736 | 3,134 | 2,517 | 4,267 | 1.3% | 1.3% | 1.3% | 1.3% | 1.2% | 1.8% | 8 | 8 | 8 | 8 |
| Brazil | 1,952 | 1,683 | 2,149 | 2,873 | 0.7% | 0.7% | 0.7% | 0.7% | 1.1% | 1.2% | 9 | 9 | 9 | 10 |
| Canada | 1,807 | 1,506 | 1,275 | 2,482 | 0.6% | 0.6% | 0.6% | 0.6% | 0.6% | 1.0% | 10 | 10 | 12 | 11 |
| Germany | 1,602 | 1,346 | 2,056 | 3,046 | 0.6% | 0.6% | 0.6% | 0.6% | 1.0% | 1.3% | 11 | 11 | 10 | 9 |
| France | 1,271 | 1,084 | 1,670 | 2,232 | 0.4% | 0.4% | 0.4% | 0.4% | 0.8% | 0.9% | 12 | 12 | 11 | 12 |
| Switzerland | 1,086 | 954 | 741 | 1,032 | 0.4% | 0.4% | 0.4% | 0.4% | 0.4% | 0.4% | 13 | 13 | 18 | 18 |
| Netherlands | 941 | 785 | 771 | 1,147 | 0.3% | 0.3% | 0.3% | 0.3% | 0.4% | 0.5% | 14 | 14 | 17 | 15 |
| Italy | 887 | 745 | 1,220 | 1,519 | 0.3% | 0.3% | 0.3% | 0.3% | 0.6% | 0.6% | 15 | 15 | 13 | 14 |
| Turkey | 677 | 482 | 952 | 973 | 0.2% | 0.2% | 0.2% | 0.2% | 0.5% | 0.4% | 16 | 18 | 15 | 19 |
| Spain | 674 | 566 | 851 | 1,131 | 0.2% | 0.2% | 0.2% | 0.2% | 0.4% | 0.5% | 17 | 17 | 16 | 16 |
| Belgium | 672 | 569 | 640 | 638 | 0.2% | 0.2% | 0.2% | 0.2% | 0.3% | 0.3% | 18 | 16 | 19 | 20 |
| Poland | 475 | 408 | 472 | 626 | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.3% | 19 | 19 | 21 | 21 |
| Mexico | 475 | 387 | 990 | 1,110 | 0.2% | 0.2% | 0.2% | 0.2% | 0.5% | 0.5% | 20 | 20 | 14 | 17 |
| Sweden | 389 | 331 | 306 | 451 | 0.1% | 0.1% | 0.1% | 0.1% | 0.2% | 0.2% | 21 | 21 | 22 | 22 |

| | | | | | | | | | | | | |
|--------------------|---------|---------|---------|---------|-------|-------|-------|-------|----|----|----|----|
| Russian Federation | 360 | 292 | 623 | 1,631 | 0.1% | 0.1% | 0.3% | 0.7% | 22 | 22 | 20 | 13 |
| Denmark | 329 | 287 | 285 | 312 | 0.1% | 0.1% | 0.1% | 0.1% | 23 | 23 | 23 | 24 |
| Ireland | 230 | 202 | 254 | 259 | 0.1% | 0.1% | 0.1% | 0.1% | 24 | 24 | 24 | 26 |
| Norway | 205 | 170 | 188 | 328 | 0.1% | 0.1% | 0.1% | 0.1% | 25 | 25 | 27 | 23 |
| Austria | 197 | 166 | 228 | 310 | 0.1% | 0.1% | 0.1% | 0.1% | 26 | 27 | 25 | 25 |
| Bulgaria | 192 | 167 | 128 | 127 | 0.1% | 0.1% | 0.1% | 0.1% | 27 | 26 | 29 | 32 |
| Czech Republic | 143 | 123 | 225 | 214 | 0.0% | 0.1% | 0.1% | 0.1% | 28 | 28 | 26 | 28 |
| Finland | 108 | 88 | 147 | 198 | 0.0% | 0.0% | 0.1% | 0.1% | 29 | 29 | 28 | 30 |
| Romania | 73 | 62 | 120 | 203 | 0.0% | 0.0% | 0.1% | 0.1% | 30 | 30 | 33 | 29 |
| Luxembourg | 66 | 61 | 60 | 59 | 0.0% | 0.0% | 0.0% | 0.0% | 31 | 31 | 35 | 36 |
| Slovak Republic | 47 | 40 | 122 | 116 | 0.0% | 0.0% | 0.1% | 0.0% | 32 | 32 | 31 | 33 |
| Greece | 41 | 36 | 121 | 222 | 0.0% | 0.0% | 0.1% | 0.1% | 33 | 33 | 32 | 27 |
| Slovenia | 34 | 28 | 41 | 60 | 0.0% | 0.0% | 0.0% | 0.0% | 34 | 34 | 36 | 35 |
| Hungary | 25 | 21 | 126 | 110 | 0.0% | 0.0% | 0.1% | 0.0% | 35 | 35 | 30 | 34 |
| Portugal | 22 | 18 | 117 | 157 | 0.0% | 0.0% | 0.1% | 0.1% | 36 | 36 | 34 | 31 |
| Estonia | 9 | 8 | 20 | 29 | 0.0% | 0.0% | 0.0% | 0.0% | 37 | 37 | 39 | 41 |
| Lithuania | 8 | 6 | 32 | 51 | 0.0% | 0.0% | 0.0% | 0.0% | 38 | 38 | 37 | 37 |
| Croatia | 7 | 6 | 31 | 48 | 0.0% | 0.0% | 0.0% | 0.0% | 39 | 39 | 38 | 38 |
| Latvia | 7 | 6 | 17 | 29 | 0.0% | 0.0% | 0.0% | 0.0% | 40 | 41 | 40 | 40 |
| Cyprus | 7 | 6 | 13 | 31 | 0.0% | 0.0% | 0.0% | 0.0% | 41 | 40 | 41 | 39 |
| Malta | 5 | 4 | 12 | 15 | 0.0% | 0.0% | 0.0% | 0.0% | 42 | 42 | 42 | 42 |
| Rest of world | 93,652 | 78,402 | 55,886 | 75,384 | 32.6% | 32.6% | 27.7% | 31.6% | | | | |
| Sum of bilaterals | 287,162 | 240,786 | 201,516 | 238,674 | 67% | 67% | 72% | 68% | | | | |
| Aggregate | 287,162 | 240,468 | 201,516 | 238,674 | | | | | | | | |

Note: Authors' calculations based on WIOD, 2016 release.

Table 11A.7 **Bilateral exports by Brazil, 2014**

| | Million US\$ | | | | | | Shares in total | | | | Ranking of countries | | | |
|--------------------|--------------|--------|--------|--------|-------|-------|-----------------|-------|-------|-------|----------------------|-------|-------|-------|
| | VAX-D | | | VAX-P | | | VAX-D | | VAX-P | | VAX-C | | GX | |
| | GX | VAX-D | VAX-P | VAX-D | VAX-P | VAX-C | GX | VAX-D | VAX-P | VAX-C | GX | VAX-D | VAX-P | VAX-C |
| China | 41,012 | 33,493 | 32,027 | 32,570 | 15.2% | 16.1% | 20.6% | 15.7% | 1 | 1 | 1 | 1 | 1 | 1 |
| United States | 29,552 | 20,999 | 18,184 | 25,488 | 10.9% | 10.1% | 11.7% | 12.3% | 2 | 2 | 2 | 2 | 2 | 2 |
| Japan | 9,054 | 7,084 | 6,202 | 8,508 | 3.4% | 3.4% | 4.0% | 4.1% | 3 | 3 | 3 | 3 | 3 | 3 |
| Netherlands | 8,682 | 6,497 | 3,385 | 3,828 | 3.2% | 3.1% | 2.2% | 1.8% | 4 | 4 | 4 | 4 | 8 | 9 |
| Germany | 7,025 | 5,359 | 4,938 | 6,015 | 2.6% | 2.6% | 3.2% | 2.9% | 5 | 6 | 5 | 6 | 5 | 4 |
| India | 6,891 | 5,654 | 5,695 | 5,804 | 2.5% | 2.7% | 3.7% | 2.8% | 6 | 5 | 4 | 5 | 4 | 5 |
| France | 4,871 | 3,879 | 3,771 | 4,737 | 1.8% | 1.9% | 2.4% | 2.3% | 7 | 7 | 6 | 7 | 6 | 7 |
| Mexico | 4,856 | 3,388 | 2,419 | 3,193 | 1.8% | 1.6% | 1.6% | 1.5% | 8 | 10 | 12 | 10 | 12 | 13 |
| United Kingdom | 4,779 | 3,840 | 3,047 | 5,107 | 1.8% | 1.8% | 2.0% | 2.5% | 9 | 8 | 9 | 8 | 9 | 6 |
| South Korea | 4,341 | 3,416 | 3,407 | 3,471 | 1.6% | 1.6% | 2.2% | 1.7% | 10 | 9 | 7 | 9 | 7 | 10 |
| Italy | 4,090 | 3,169 | 2,908 | 3,290 | 1.5% | 1.5% | 1.9% | 1.6% | 11 | 11 | 10 | 11 | 10 | 11 |
| Russian Federation | 3,656 | 2,833 | 1,125 | 4,055 | 1.4% | 1.4% | 0.7% | 2.0% | 12 | 12 | 18 | 12 | 18 | 8 |
| Canada | 3,495 | 2,600 | 2,300 | 2,949 | 1.3% | 1.2% | 1.5% | 1.4% | 13 | 15 | 14 | 13 | 14 | 14 |
| Indonesia | 3,476 | 2,736 | 2,851 | 3,209 | 1.3% | 1.3% | 1.8% | 1.5% | 14 | 13 | 11 | 13 | 11 | 12 |
| Spain | 3,302 | 2,601 | 2,418 | 2,632 | 1.2% | 1.2% | 1.6% | 1.3% | 15 | 14 | 13 | 14 | 13 | 15 |
| Belgium | 3,121 | 2,408 | 1,296 | 2,013 | 1.2% | 1.2% | 0.8% | 1.0% | 16 | 16 | 17 | 16 | 17 | 16 |
| Taiwan | 2,572 | 2,058 | 1,637 | 1,723 | 1.0% | 1.0% | 1.1% | 0.8% | 17 | 17 | 15 | 17 | 15 | 18 |
| Norway | 1,708 | 1,362 | 855 | 1,095 | 0.6% | 0.7% | 0.5% | 0.5% | 18 | 18 | 20 | 18 | 20 | 20 |
| Turkey | 1,677 | 1,280 | 1,509 | 1,504 | 0.6% | 0.6% | 1.0% | 0.7% | 19 | 19 | 16 | 19 | 16 | 19 |
| Portugal | 1,185 | 940 | 720 | 849 | 0.4% | 0.5% | 0.5% | 0.4% | 20 | 21 | 21 | 21 | 21 | 21 |
| Australia | 1,164 | 942 | 1,086 | 1,943 | 0.4% | 0.5% | 0.7% | 0.9% | 21 | 20 | 19 | 20 | 19 | 17 |

| | | | | | | | | | | | |
|-------------------|---------|---------|---------|---------|-------|-------|-------|----|----|----|----|
| Denmark | 908 | 744 | 556 | 531 | 0.3% | 0.4% | 0.3% | 22 | 22 | 23 | 26 |
| Ireland | 832 | 606 | 293 | 654 | 0.3% | 0.2% | 0.3% | 23 | 23 | 29 | 25 |
| Sweden | 697 | 546 | 498 | 712 | 0.3% | 0.3% | 0.3% | 24 | 24 | 24 | 24 |
| Poland | 646 | 510 | 589 | 760 | 0.2% | 0.2% | 0.4% | 25 | 25 | 22 | 22 |
| Switzerland | 561 | 424 | 413 | 740 | 0.2% | 0.3% | 0.4% | 26 | 27 | 25 | 23 |
| Finland | 560 | 435 | 362 | 397 | 0.2% | 0.2% | 0.2% | 27 | 26 | 26 | 28 |
| Romania | 347 | 273 | 328 | 383 | 0.1% | 0.1% | 0.2% | 28 | 28 | 27 | 29 |
| Austria | 341 | 265 | 319 | 491 | 0.1% | 0.1% | 0.2% | 29 | 29 | 28 | 27 |
| Slovenia | 323 | 254 | 243 | 251 | 0.1% | 0.1% | 0.1% | 30 | 30 | 30 | 32 |
| Bulgaria | 195 | 163 | 137 | 147 | 0.1% | 0.1% | 0.1% | 31 | 31 | 34 | 34 |
| Hungary | 187 | 142 | 189 | 169 | 0.1% | 0.1% | 0.1% | 32 | 33 | 32 | 33 |
| Greece | 183 | 148 | 202 | 330 | 0.1% | 0.1% | 0.2% | 33 | 32 | 31 | 30 |
| Czech Republic | 143 | 110 | 182 | 271 | 0.1% | 0.1% | 0.1% | 34 | 34 | 33 | 31 |
| Slovak Republic | 65 | 48 | 121 | 128 | 0.0% | 0.1% | 0.1% | 35 | 36 | 35 | 35 |
| Croatia | 61 | 49 | 65 | 91 | 0.0% | 0.0% | 0.0% | 36 | 35 | 36 | 36 |
| Estonia | 50 | 34 | 30 | 50 | 0.0% | 0.0% | 0.0% | 37 | 38 | 39 | 40 |
| Lithuania | 46 | 36 | 50 | 88 | 0.0% | 0.0% | 0.0% | 38 | 37 | 38 | 37 |
| Cyprus | 42 | 31 | 20 | 56 | 0.0% | 0.0% | 0.0% | 39 | 39 | 41 | 39 |
| Latvia | 30 | 23 | 28 | 46 | 0.0% | 0.0% | 0.0% | 40 | 40 | 40 | 41 |
| Luxembourg | 29 | 24 | 54 | 77 | 0.0% | 0.0% | 0.0% | 41 | 40 | 37 | 38 |
| Malta | 22 | 15 | 13 | 26 | 0.0% | 0.0% | 0.0% | 42 | 42 | 42 | 42 |
| Rest of world | 113,484 | 87,038 | 49,074 | 76,775 | 42.0% | 41.8% | 37.1% | | | | |
| Sum of bilaterals | 270,263 | 208,455 | 155,545 | 207,157 | 58% | 58% | 63% | | | | |
| Aggregate | 270,263 | 208,346 | 155,545 | 207,157 | | | | | | | |

Note: Authors' calculations based on WIOD, 2016 release.

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