# Structural Change in Exports

## From Product to Functional Specialization in Trade

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**Abstract** Trade analysis on the basis of countries' export baskets can be misleading when production is globally fragmented. The chapter argues for a switch to analysis of the type of activities that are embodied in exports. The chapter discusses two steps towards this goal. It first discusses the transition in trade studies from product to vertical specialization. A country's vertical specialization in trade is measured as the share of domestic value added in its gross exports. The chapter identifies three waves of vertical specialization in the world economy since 1970, and documents the servicification of manufacturing exports. Results from cross-country analysis show a robust association between specialization and productivity growth, but not between specialization and employment growth. Next, the chapter considers functional specialization in trade based on the measurement of distinct activities in export such as fabrication, marketing and R&D, based on an occupational classification of workers. It documents how advanced economies continued to specialize in headquarter activities, while quickly moving out of fabrication activities. It also shows that there are many idiosyncratic determinants of a country's specialization pattern beyond its general development level. The chapter ends with suggestions for further research, given that the measures of trade in value added and activities presented are still in a development phase.

# 15.1 Introduction

The aim of this chapter is to provide an overview of trends in countries' structure of production for exports, explicitly taking into account the emergence of international production networks.[1] The classical Heckscher-Ohlin view of trade links a country's export pattern to its endowments. To this end, products are typically classified according to the factor input intensities of the parenting industries such as primary products which are intensive in natural resources and land, simple manufactured products which are intensive in unskilled labour, and sophisticated goods intensive in skilled labour and capital. Lall (2000) and others refined this classification by emphasizing knowledge as an additional resource, distinguishing manufacturing goods by their technology level. At a broad level, endowment differences across poor and rich regions seem to explain existing patterns of product specialization in trade, as shown for example in early work by Leamer (1984) and Hanson (2012) using detailed product trade statistics. More recent in the literature is a shift in focus away from studying specialization in product groups (for example footwear versus passenger cars) towards specialization in varieties within narrowly defined product categories (for example passenger cars with small or big engines). To this end use is made of detailed information on unit values of exported goods.[2] Schott (2004) provided evidence of within-product specialization, with the skill- and capital-abundant countries specializing in the production and export of higher unit-value products, and unskilled-labour-abundant countries specializing in the production and export of low-unit-value products. In other words, accepting Schott's premise that unit values within very narrowly defined product categories reflect differences in product 'quality', these findings imply that developed countries

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[2] An export unit value is calculated as the value of the exported product divided by its quantity and reflects the average price of the product category (at the ten-digit HS level).

specialized in higher quality goods while developing countries specialized in lower quality goods in the period studied (1972–1994).[3]

Yet, ongoing developments in the global economy, in particular the rapid fragmentation of production across borders, muddle the interpretation of product trade statistics as indicative of a country's capabilities. Global production networks have emerged in which various stages of production are carried out at different geographical locations, often coordinated by a multinational enterprise (Gereffi 1994, 1999, Buckley et al. 2020). This process accelerated in the 2000s with the opening of China to the global economy as exemplified by its accession to the WTO in 2001. Lall (2000) was one of the first to point out that international production fragmentation posed a major threat to a clean interpretation of trade statistics as it 'does not indicate the *process* involved in making the same product in different locations. Thus, a high technology product like semiconductors can involve genuinely high-tech processes in the USA and relatively simple assembly in Malaysia. In our data both would appear equally technologically advanced' (Lall 2000, p. 340). Yet, standard trade analysis still equates the characteristics of the product exported with the activities in export production. For example, Rodrik stated in 2006 that 'China is an outlier in terms of the overall sophistication of its exports: its export bundle is that of a country with an income per capita level three times higher than China's. China has somehow managed to latch on to advanced, high-productivity products that one would not normally expect a poor, labour abundant country like China to produce, let alone export' (Rodrik 2006, p. 4).[4] Chen et al. (2012) and Koopman et al. (2012) pointed out

[3] An alternative typology of goods is provided in terms of product complexity by Hidalgo et al. (2007). This line of work is surveyed by Freire in Chapter of this volume. One might also categorize products through differences in demand elasticities as in Reinert (2007) who distinguishes between Schumpeterian and Malthusian goods.

[4] See Schott (2008) for a moderated version of this view, pointing out that 'while China's export overlap with the OECD is much greater than one would predict given its low wages, the prices that US

that production of Chinese exports relied heavily on the use of imported intermediates. For example, the actual value added by Chinese firms was found to be only 19 per cent of gross export value in the case of electronics and computers in 2002. In a classic case study, Dedrick et al. (2010) found that the Chinese value-added contribution to its gross exports of Apple's iPod was even less than 4 per cent. China mainly performed assembly, testing, and packaging activities on imported high-tech components while relying on software, supply-chain orchestration, and branding from foreign companies. International fragmentation of production processes clearly confound conclusions on countries' production capabilities that are drawn from export patterns, no matter how detailed the product export statistics are.[5]

In response to the changes in global trade patterns so-called trade-in-value-added statistics were developed, stimulated, and promoted by the OECD/WTO Trade-in-Value-added (TiVa) project in the early 2010s. These statistics provide complementary information on the domestic content of countries' exports using data on value added and intermediate input use as recorded in so-called input–output tables.[6] This was a useful step towards a better understanding of countries' engagement in trade and the relation between trade involvement, structural change, and economic development. Yet, while the new measures are informative of a country's value-added contribution to its exports, they are still silent about the characteristics of the tasks carried out by the exporting country. This is salient as countries appear to be specializing in particular

consumers are willing to pay for China's exports are substantially lower than the prices they are willing to pay for OECD exports' (p. 1).

[5] For example, the description of six-digit HS code 847130, the most detailed level at which export data is collected, reads: 'Automatic data processing machines; portable, weighing not more than 10kg, consisting of at least a central processing unit, a keyboard and a display.'

[6] Input–output tables provide information on the production structures of industries and the structure of consumption in a country in a coherent accounting framework such that the use of products equals supply (see Miller & Blair (2009) for an introduction).

tasks in global production networks rather than in particular products. The aim of this chapter is to argue the need for a task-based perspective on changes in the structure of production and trade. This requires considering the (vertically) integrated structure of production in the tradition of Sraffa (1960) and Pasinetti (1981) using information from input–output tables. These older studies were mainly focused on the integration of domestic industries. We argue for an extension of this view and the need for analysing integration of production across borders taking account of all stages of production, domestic and abroad.

In short, we advocate analysis of trade in value added while explicitly accounting for the particular tasks that countries perform in global production networks. Using the task-based approach, we will show that countries specialize in carrying out particular tasks (or functions as we will call them alternatively) such as R&D, logistics, marketing, or fabrication, rather than specializing in producing particular goods or services. Put otherwise, we draw attention to the process of functional specialization in trade in contrast to the traditional focus on product specialization in trade. This is opening up new avenues of research that may connect studies of international trade with studies of economic geography, of international business, and of labour markets. Functions not only differ in their demand for factor inputs but also in their propensity to be relocated. For example, agglomeration forces are likely to induce spatial inertia in R&D activities, but are much less relevant for the location of assembly activities. Functions are also likely to differ in their potential for productivity growth and in the generation of spillovers. Moreover, new developments in automation and robotization will differentially affect various tasks, such that (potential) substitution of machines for workers is best analysed through a task lens (Acemoglu & Autor 2011). All in all, we believe that a task-based perspective generates new insights into the changing structure of international trade and invites novel analyses of the underlying determinants.

The remainder of the chapter is organized as follows. In Section 15.2, we outline the main input–output methodology used to trace domestic value added in exports along with the functional content of these exports. This section further provides a short discussion of the data that are currently available along with appropriate caveats for proper interpretation. In particular, two recently developed databases are described. Pahl & Timmer (2019) provide national input–output tables for ninety-one countries going back to the 1970s, providing the opportunity to study trends in the domestic value added that is embodied in export baskets for a wide range of countries. The database introduced in Timmer et al. (2019) contains information on the occupational structure of industries in forty countries for the period from 1999 to 2011, which allows for the construction of indicators of the functional content of exports. Section 15.3 of the chapter presents evidence using the dataset of Pahl & Timmer (2019) to highlight four global trends in trade. In general, there is a declining trend in the share of domestic value added in global exports, a process commonly referred to as vertical specialization in trade. At the same time we find a great deal of heterogeneity in terms of vertical specialization patterns across countries, and a movement towards servicification of manufacturing exports over time. Building upon these results, Section 15.4 moves away from the study of vertical specialization to consider functional specialization in trade based on the measurement of distinct functions in export production, identifying new facts about the structure of production for trade. The section discusses available information for a functional typology, which is mainly based on an occupational classification of workers. It shows how the task structure of export production differs across countries and changes over time, further characterizing the observed changes in vertical specialization highlighted in Section 15.3. Finally, Section 15.5 provides concluding remarks. Amongst others, we emphasize that the composite measures of trade in value added and functions presented in this chapter are still in a development phase and should be considered as a complement to rather than a substitute for the traditional product trade statistics that have a high level of granularity.

## 15.2 Measuring Specialization in Trade

In an influential contribution, Hummels et al. (2001) proposed a new metric of 'vertical specialization in trade' measured as the share of domestic value added in gross exports.[7] This share is one when all activities needed to produce exports are performed within the exporting country. The share is declining in the amount of intermediates imported. To track this share one needs to complement product export statistics by information on value added. Importantly, this is the value added by the exporting industry (in the last stage of production), but also by other domestic industries in upstream stages of production. To do so, Hummels et al. (2001) relied on a procedure that was originally developed by Leontief (1953).[8] Timmer et al. (2019) built upon this framework by further decomposing value added by different type of workers to track functional specialization in trade. In this section we outline the measurement framework and discuss the available data sources.

[7] To be precise, Hummels et al. (2001) defined a measure which they called the 'import content of exports'. Koopman et al. (2012) defined the 'domestic value added in exports' and showed that it is equal to gross exports minus the 'import content of exports'. We follow the 'domestic value added' terminology as it can be clearly contrasted with other trade measures in a unified framework as shown in Los & Timmer (2018).

[8] Less well known, Chenery et al. (1986) provide similar analyses that foreshadow this work, building upon the work on linkages by Hirschman (1958). See Miller & Blair (2009) for an introduction into input–output analysis.

## 15.2.1 Method

Let $\mathbf{e}$ be a vector of exports (of dimension $G \times 1$) with $G$ the number of goods and services in the economy.[9] Let $\mathbf{A}^{\boldsymbol{D}}$ be the $G \times G$ domestic coefficient matrix with typical element $a_{st}$ indicating the amount of *domestic* product $s$ used in the production of one unit of $t$ (in nominal terms). We can then derive a vector $\mathbf{y}$ ($G \times 1$) which represents the total gross output needed in each industry to produce exports as:

$$\mathbf{y} = (\mathbf{I} - \mathbf{A}^{\boldsymbol{D}})^{-1}\mathbf{e} \qquad (1)$$

where $\mathbf{I}$ is a $G \times G$ identity matrix with ones on the diagonal and zeros elsewhere, and $(\mathbf{I} - \mathbf{A}^{\boldsymbol{D}})^{-1}$ is the well-known Leontief inverse matrix which ensures that all output related to exports is taken into account, not only the output of the industry that is exporting, but also of other domestic industries that contribute through the delivery of intermediate inputs.[10] The Leontief inverse summarizes all prior production steps as it can be written as a geometric series: $(\mathbf{I} - \mathbf{A}^{\boldsymbol{D}})^{-\mathbf{1}} = \mathbf{I} + [\mathbf{A}^{\boldsymbol{D}}] + [\mathbf{A}^{\boldsymbol{D}}]^{\mathbf{2}} + \ldots + [\mathbf{A}^{\boldsymbol{D}}]^{\infty}$. This is under the assumption that the production technology as represented by $\mathbf{A}^{\boldsymbol{D}}$ is the same in all stages of production.[11]

[9] In the set-up of models of value added trade, each product is uniquely associated with one particular industry, so G is also the number of industries.

[10] It should be noted that this procedure provides an analysis of value added in the various stages of production of a final good or service. It does not include value added in the distribution of the product from the producer to the consumer. This is because the distribution sector is represented as a so-called margin industry in input–output tables. Chen et al. (2018) provide a first attempt to also trace value added in the distribution stage, showing that this value can be large compared to the value added in production, highlighting the importance of intangible capital such as brand names, for example, in wearing apparel. Gereffi (1999) provides a qualitative discussion of the role of retailers in driving global production networks of textiles.

[11] See Nomaler & Verspagen (2014) for a critical discussion of this assumption.

To find the domestic value added related to the production of exports, one needs to pre-multiply industry output by **V,** the matrix ($G \times G$) with diagonal element $v_{gg}$ representing the value added to gross output ratios for industry $g$ and zeroes elsewhere:

$$\mathbf{d} = \mathbf{V}\mathbf{y} \qquad (2)$$

where vector **d** ($G \times 1$) is the amount of domestic value added needed for a country's exports. Note that **d** contains value added generated in industries that export as well as other domestic industries that contribute through the delivery of intermediate inputs.[12] Summing across all industries one arrives at the total domestic value added in a country's exports, referred to as VAX-D. We express this sum as a share of gross exports and refer to this ratio as the VAX-D ratio. For a particular country, it is defined as:

$$VAX\ D\ ratio \quad = \frac{VAXD}{e^{tot}} \qquad (3)$$

where $e^{tot}$ is the sum of exports (i.e. $e^{tot} = \mathbf{1}'\mathbf{e}$ , with $\mathbf{1}'$ a transposed (summation) vector of ones), and $VAX\ D = \mathbf{1}'\mathbf{d}$ the sum of value added to exports across industries. This ratio is bound between zero and one, with a lower value indicating a higher level of vertical specialization in trade.[13]

[12] Firm-level studies focus only on value added by firms that actually export (e.g. Del Prete et al. 2017; Foster-McGregor et al. 2014; Okafor et al. 2017). Yet with production fragmentation, other domestic firms might indirectly contribute by delivering inputs to the exporting firms.

[13] The VAX-D ratio is related, but different, from the well-known VAX-C ratio measure introduced by Johnson & Noguera (2012), especially at the bilateral and/or sector level of analysis. For example, VAX-D in manufacturing exports captures all domestic value added in products exported by the manufacturing sector. This value added is generated in the production chain that includes the manufacturing industry that exports, but also other manufacturing and non-manufacturing industries (such as agriculture, mining, and services). In contrast, the manufacturing VAX-C measure captures how much value added is generated in the manufacturing industry that is ultimately absorbed abroad, embodied in exports by all industries. Put otherwise, while the measurement of VAX-C is based on tracing forward linkages in the use of manufacturing value added, VAX-D is based on tracing

Timmer et al. (2019) extend this approach to account for the functional content of exports as follows.[14] Let **B** be a matrix of dimension $K \times G$, where $K$ is the number of different functions. A typical element of this matrix ($b_{kg}$) denotes the income of all workers performing function $k$ in industry $g$, expressed as a share of value added in $g$. Then:

$$\mathrm{f} = \mathbf{Bd} \tag{4}$$

where vector $\boldsymbol{f}$ of dimension $(K \times 1)$ with typical element $\mathrm{f}^k$ represents value added by function $k$ in a country's exports. Combining (1), (2), and (4), we can write:

$$\mathbf{f} = \mathbf{BV}(\mathbf{I} - \mathbf{A}^{\boldsymbol{D}})^{-1}\mathbf{e} \tag{5}$$

This is our key equation to measure the domestic value added by each task in a country's exports. When vector **e** includes all exports made by the country, then the calculated vector **f** will contain elements $\mathrm{f}^k$, the domestic value added from function $k$ in the country's exports.[15]

The elements of **f** are subsequently used to calculate the so-called functional specialization index introduced by Timmer et al. (2019). Let subscript $i$ be a country and define $\mathrm{f}_i^k$ as the income from function $k$ in country $i$'s exports. The functional specialization (FS) index for function $k$ in country $i$ is defined as:

$$\mathrm{FS}_i^k = \frac{\left(\mathrm{f}_i^k / \sum_k \mathrm{f}_i^k\right)}{\sum_i \mathrm{f}_i^k / \sum_i \sum_k \mathrm{f}_i^k} \tag{6}$$

backward linkages in the production of manufacturing exports (see Los & Timmer (2018) for further discussion).

[14] This procedure is often used in studies of the factor content of trade, following Leontief (1953). This particular application resembles Wolff (2003) who analysed the changing worker occupation content of US exports. Labour content is typically stated in quantities such as number of workers. Here we want to track the value added of workers as measured by their labour income.

[15] By appropriately expanding the dimensions of the matrices, one can also keep track of the industry in which the value is being added.

The numerator measures the share of function $k$ in overall labour income in country $i$'s exports. The denominator calculates the income share of this function for all countries in their exports. If the index is above one, the country is said to be specialized in that function.[16]

### 15.2.2 Data Sources

To measure the VAX-D ratios in Equation (3) and FS index in Equation (6) we require national input–output (IO) tables and data on the occupational content of the labour force. Pahl & Timmer (2019) developed input–output data for ninety-one countries, covering the period from 1970 to 2013. All data were compiled for fourteen manufacturing industries and five additional broad sectors, together covering the whole economy, classified by the industrial classification (ISIC) Revision 3.1. A major challenge in their data construction was the derivation of consistent time-series of value added to gross output ratios at a detailed industry level (**v**). These were derived from the UNIDO INDSTAT2 database for disaggregated manufacturing industries, harmonized and adjusted to account for breaks in the series, for example, due to changes in the industrial classifications or in the survey methodology used in reporting countries. For other (non-manufacturing) broad sectors, the variables are retrieved from United Nations Official Country Data and UN National Accounts Estimates of Main Aggregates. Having series of **v** at annual frequency in the data is crucial for the study of international production fragmentation. The 'fine slicing' of production processes brings down the value added to gross output ratios of all the countries involved. Being able to track changes in **v** over

[16] The functional specialization index is a variant of the well-known Balassa index (Balassa 1965). If, according to Ricardian trade theory, differences in relative productivity determine the pattern of trade, then the (observable) pattern of trade can be used to infer (unobservable) differences in relative productivity in some cases as shown in French (2017). See Chapter 19 by Dosi & Tranchero in this volume for a critical discussion of comparative advantage as a driver of international trade patterns, favouring absolute advantage instead.

time is thus paramount.[17] UNIDO obtains its data from national statistical agencies, which follow UNIDO's guidelines for definitions (such as the concepts of value added and output) as well as for sampling and data collection. Data are typically based on a survey of medium- and large-scale firms, sampled from the population of firms reported in economic censuses or business registers often with a cut-off in terms of employment. A typical sample would include all firms with ten employees or more such that small scale firms are excluded.

A further challenge in constructing these data involves the derivation of the domestic intermediate input coefficients matrix, $\boldsymbol{A}^{\boldsymbol{D}}$. For each country a benchmark matrix for a particular year was chosen, extrapolating to other years using a technique that makes maximum use of country-specific (annual) information on exports, imports, value added, and gross output. For the benchmark matrices Pahl & Timmer (2019) used tables for thirty-four countries from the WIOD (Timmer et al. 2015), tables for another sixteen countries from the OECD-TiVA database (benchmark year 2005, available at oe.cd/tiva) and for another fifteen countries from the GTAP 7 release (benchmark year 2004, see Narayanan & Walmsley 2008).[18] For an additional twenty-six countries a benchmark matrix was approximated using country-specific information on exports, imports, and sectoral gross output and value added. Full details can be found in Pahl & Timmer (2019). This data will be used in Section 15.3 of this chapter.

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[17] In the limit, when all intermediates are imported, the VAX-D ratio equals the value added to gross output ratio of the exporting industry.

[18] See contributions in Dietzenbacher & Tukker (2013) for an in-depth review of available IO data sources. Note that the tables do not provide information on heterogeneity in production patterns within industries. The study of Koopman et al. (2012) led to a general recognition of the importance of accounting for heterogeneity in import use across different types of firms, in particular those located in export processing zones that typically use more imported inputs. Using detailed data on imports and exports of Mexican firms, de Gortari (2017) finds that import intensities of output can also vary across destination markets.

The data discussed so far allows one to derive measures of vertical specialization. An important additional quandary in understanding functional specialization is how to define a function which is a set of activities that 'go together' and conversely, where to draw the boundaries between activities that are 'different'. This is a complicated matter, both conceptually and empirically, in particular since these boundaries may change over time as the 'glue' that binds activities together might dissolve due to technological advances (Baldwin 2016). A typical distinction that has been made is between production and non-production (supporting) activities. Naively, value added from manufacturing industries could be equated with production activities and value added from services industries with supporting activities. But functions are different from industries and there is no simple one-to-one mapping. Administrative data, following the international standard industrial classification (ISIC), is organized through classifying establishments (or firms) by their primary activity, which is the activity that makes the largest contribution to value added. In practice, establishments perform various activities and combine these in-house (Bernard et al. 2017). Importantly, this mix is changing over time, due to a phenomenon known as 'servicification of manufacturing' in advanced countries (Miroudot & Cadestin 2017). Crozet & Milet (2017) find that in 2007 40 per cent of French firms classified as manufacturing sold more services than goods. Kelle (2013) found a large shift in German manufacturing firms towards services exports, for example, in installing and maintaining machinery. Bernard & Fort (2015) document the rise of factoryless goods producers in the United States. These firms design the goods they sell and coordinate production networks, yet are not actually engaged in fabrication activities. They might be classified as wholesalers or as manufacturers in the current US industrial statistical system. Fontagné & Harrison (2017) provide wider evidence of this phenomenon. This indicates that we cannot rely on a mere statistical classification of firms into industries in order to understand what activities they carry out.

Timmer et al. (2019) take a pragmatic solution that is inspired by studies of offshoring behaviour of multinationals and allows for quantification across a large set of countries with available data sources. They map employment and wage data organized by occupational class to four so-called business functions: fabrication, R&D and technology development (abbreviated R&D), sales and distribution activities (marketing), and other support activities (management). These groups constitute a relevant level of analysis as multinational firms typically organize their activities around these functions due to internal economies of scale (Porter 1985). Recent research confirms that business functions define the boundaries of activities that are co-located in particular locations, and are the relevant unit in firms' decisions to offshore (Sturgeon & Gereffi 2009; Nielsen 2018). These functions also differ in their demand for factor inputs as well as in their propensity to be relocated. For example, agglomeration forces are likely to induce spatial inertia in R&D activities, yet are much less relevant for assembly, testing, or packaging activities (Mudambi et al. 2018). These activities are also likely to differ in their potential for productivity growth and in the generation of knowledge and other spillovers. Timmer et al. (2019) provide the occupational distribution for each country-industry in the WIOD (2013 release).[19] This dataset will be used in Section 15.4 of this chapter.

## 15.3 Vertical Specialization in Trade: Trends

In this section we provide an overview of trends in vertical specialization in the world since 1970. We use the methods and data as described in the previous section from Pahl & Timmer (2019). We have data for seventy-four countries for the period 1970–2013 and for ninety-one countries for the period 1995–2010, the latter period including seventeen countries for which

[19] The data is publicly available at https://doi.org/10.1093/jeg/lby056.

no long-run data are available, including most notably China. Throughout the empirical analysis, we focus on domestic value added generated in the production of manufactured exports and exclude exports from mining and agriculture.[20]

We organize the discussion around four main trends:[21]

1. Strong declining trend in the world VAX-D to gross exports ratio
2. Manufacturing exports increasingly contain non-manufacturing value added
3. Three waves of vertical specialization in the world economy
4. Country heterogeneity in vertical specialization trends.

### 15.3.1 Trend 1: Strong Declining Trend in World VAX-D Ratio

Figure 15.1 presents the global trend in the VAX-D ratio, defined as the sum of VAX-D across all countries divided by their sum of gross exports. It shows a strong declining trend in the VAX-D ratio for manufacturing exports over time, signifying a long-run process of vertical specialization in the global economy. The ratio was around 0.87 in the early 1970s, declining steadily to below 0.70 in the early 2010s, with a noticeable acceleration in this declining trend in the 1990s. The timing of this acceleration is congruent with the finding of Johnson & Noguera (2012) who traced the global VAX-C ratio for total exports based on data for a limited set of

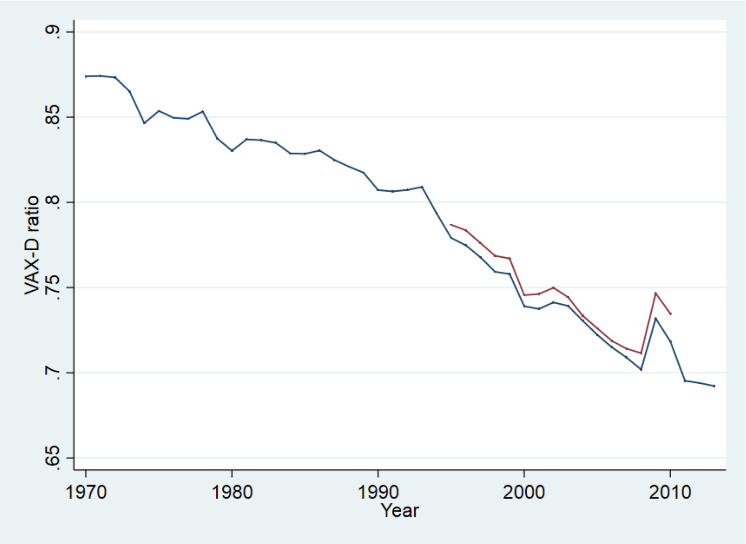
[20] By nature, the production of mining and agricultural products contains a large share of location-bound inputs such that the share of domestic value added in their exports is close to one and not particularly interesting to trace. It should be remembered though that these sectors also contribute value added to manufacturing exports through the delivery of intermediates as will be shown below.

[21] This section relies heavily on analyses presented in Pahl & Timmer (2019). The reader is referred to this work for further findings and discussion. Trend 2 is not one discussed in Pahl & Timmer (2019) and is newly identified in this chapter.

mostly high-income countries. The trend was halted in 2009, coinciding with the great global trade collapse.

The detailed data allows one to investigate trends in world VAX-D ratio for exports from twelve manufacturing industries. It reveals heterogeneity in the level of vertical specialization across industries as well as in the trends over time. By 2010, exports of chemical and transport equipment industries are among the most import-intensive activities, while exports of food rely much more on domestically produced intermediates (see Appendix Table A15.1). Exports of the petroleum refining industry stand out as being the most import-intensive which is consistent with the fact that many countries need to rely on imported petroleum in the production of refined fuels. All industries (except oil refining) share a long-run decline in the global VAX-D ratio over the period 1970–2013, albeit at different speeds. The world VAX-D ratio for exports of textiles (industries 17, 18, and 19 in the ISIC rev. 3 classification) declined from 0.87 in 1970 to 0.75 in 2013. In contrast, exports of machinery (including electronics, industries 29, 20, 31, 32, and 33 in ISIC rev. 3) were not intensive in imports in 1970 (VAX-D ratio of 0.92), but rapidly became more import-intensive over time (0.70 in 2013).

**Figure 15.1** World VAX-D ratio for exports by all manufacturing industries



Note: World VAX-D ratio is the sum of VAX-D across all countries divided by their sum of gross exports. World VAX-D ratio for 74 countries for 1970-2013 (in blue) and for 91 countries for 1995-2010 (in red). Figure is taken from Pahl and Timmer (2019).

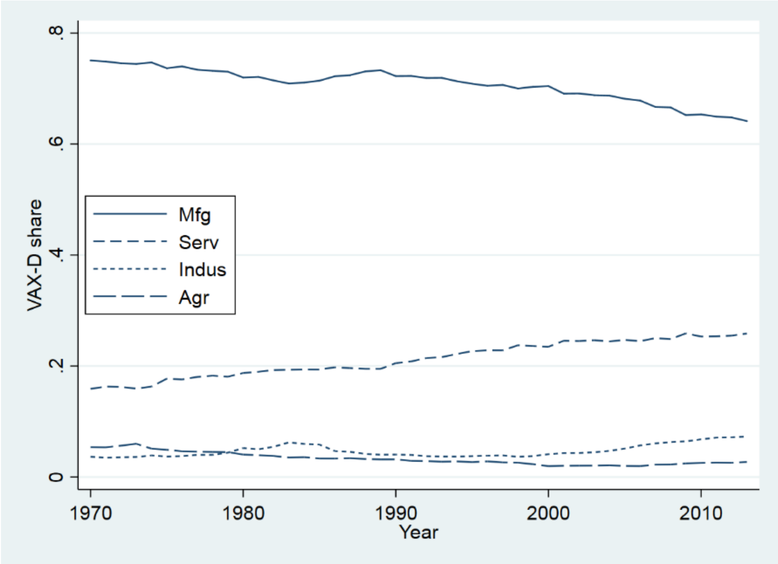
In a decomposition of the world VAX-D ratio, Pahl & Timmer (2019) showed that countries have on average shifted into the export of products such as machinery and transport equipment that require relatively more imported intermediates. This product mix effect is minor however, accounting for about 0.02 of the 0.14 points decline in the ratio over the period 1986–2011. More important is the decline in the value added to gross output ratios within industries, which accounts for about 0.04 points of the decline. This reflects a finer slicing of production processes via the outsourcing and offshoring of production stages such that domestic (own-industry) factor inputs are substituted by intermediates. Interestingly, they find that the product mix of intermediates has shifted towards intermediates that are on average produced domestically rather than imported, namely services, which has the effect of increasing rather than decreasing the VAX-D ratio (by 0.01 point). Yet within each of the intermediate input categories (goods and services) there has been a massive substitution away from domestic and towards imported intermediates. This substitution channel is by far the most important driver of the declining world VAX-D ratio, accounting for 0.09 points of the decline.

### 15.3.2 Trend 2: Manufacturing Exports Increasingly Contain Non-Manufacturing Value Added

One of the interesting insights in the literature on vertical specialization is that exports of value added originate not only from the sector that is exporting but also includes value added generated in other domestic industries in upstream stages of production. To illustrate this, we provide a mapping of the domestic value added exported in manufacturing goods into the sectors that generated the value added. The results are shown in Figure 15.2. The figure shows that in the early 1970s, about 75 per cent of the domestic value added that was contained in the export of manufacturing goods originated in the domestic manufacturing sector, 16 per cent in the services sector, 5 per cent in the agriculture sector and 4 per cent in other industries. The share of the manufacturing sector dropped gradually to 64 per cent in 2013. Most of this was substituted for by value added in the services sector, which increased its share to 26 per cent. This is consistent with an increasing importance of domestic services as inputs into the production of manufactured goods, also known as the servicification of manufacturing (discussed in Section 15.3). The share of agriculture dropped to a mere 3 per cent in 2013 while other industries increased their contribution to 7 per cent. A similar pattern of substitution away from manufacturing value added towards services value added is visible when constructing the sectoral mapping for ninety-one countries in the dataset over the period 1995–2010 (results are not shown for reasons of brevity).

Johnson (2014) makes this point more generally. He finds for 2008 that manufacturing goods account for nearly 70 per cent of gross exports worldwide, with services accounting for just 20 per cent. In contrast, manufacturing and services industries both account for about 40 per cent of total value-added exports (Johnson 2014, Figure 1). Most of the value added by services sectors is through delivering intermediates to manufacturing production whose output is subsequently exported. This has major consequences for the analysis of trade. For example, Koopman et al. (2014, Figure 2) showed that when considering gross exports Japan was not specialized in business services in 2004 (as the revealed comparative advantage (RCA) index is smaller than one), while India was. In terms of sectoral value added, the situation is reversed however, with Japan exporting many services indirectly through the export of manufacturing goods. Taking account of upstream stages of production is thus crucial for a better understanding of the relationship between trade and structural change in production.

**Figure 15.2** Sectoral shares in world VAX-D in manufacturing exports




Note: Shares of four industry groups in total VAX-D in manufacturing exports at the world level. The sectors are Manufacturing (Mfg), Services (Serv), Agriculture (Agr) and Mining, Electricity and Construction (Indus). Own calculations based on data for 74 countries underlying Pahl and Timmer (2019).

### 15.3.3 Trend 3: Three Waves of Vertical Specialization in the World Economy

To investigate variation in the intensity of vertical specialization in the global economy, Pahl & Timmer (2019) employ econometric trend analysis. They trace for each country-year whether it is in a period of vertical specialization (VS), that is, whether the country-year is in a period where the trend in the VAX-D ratio for the country is negative and significantly different from zero. To this end, they estimate break points in the series of the VAX-D ratios following the methodology of Bai & Perron (1998, 2003). Having obtained the break points, they estimate linear trends between them to identify whether the period is one of declining VAX-D ratio (negative, significant coefficient), constant VAX-D ratio (insignificant coefficient) or increasing VAX-D ratio (positive, significant coefficient). We summarize their results by regional grouping and by period in Table 15.1. Geographical regions are given in column (1).

Column (2) indicates how many countries in the region initiated at least one period of VS. The results show that seventy-nine out of the ninety-one countries initiated a period of VS at some point during 1970–2013. Results in columns (3)–(8) present the number of country-year observations in a period of VS as a share of all country-year observations in the group. For example, of all country-years observations between 1970 and 1979, 59.0 per cent are in a country which experiences a period of VS at that point in time. The higher the share, the more broad-based the process of VS in the region.

**Table 15.1: Share of country-years in periods of vertical specialization**

| Country group | (1)<br>No. of countries | (2)<br>No. of countries with VS | (3)<br>1970–1979 | (4)<br>1980–1985 | (5)<br>1986–1994 | (6)<br>1995–2008 | (7)<br>2009–2013 |
|---|---|---|---|---|---|---|---|
| All countries | 91 | 79 | 59.0 | 52.7 | 61.5 | 57.9 | 47.7 |
| Developed | 18 | 18 | 85.9 | 71.6 | 78.3 | 78.2 | 66.7 |
| Developing | 73 | 61 | 51.0 | 47.3 | 56.9 | 52.9 | 42.7 |
| | | | | | | | |
| E. & S. Asia | 10 | 10 | 80.7 | 62.7 | 68.9 | 44.9 | 31.9 |
| S. America | 8 | 8 | 40.0 | 52.1 | 81.9 | 67.9 | 62.5 |
| Central America | 9 | 7 | 44.4 | 44.4 | 60.5 | 51.6 | 55.6 |
| Sub-Saharan Africa | 11 | 9 | 63.6 | 63.6 | 64.6 | 59.1 | 54.5 |
| Mid. East & N. Africa | 15 | 9 | 34.3 | 21.4 | 28.5 | 31.9 | 20.0 |
| E. Europe & C. Asia | 20 | 18 | 48.6 | 50.0 | 54.2 | 64.2 | 45.0 |

Note: Shares derived by count of country-year observations which are in a period with a significant decline in the VAX-D ratio divided by all country-year observations in a period. Significance of period break points based on Bai & Perron methodology.

Source: Data taken from Pahl & Timmer (2019).

The results in Table 15.1 suggest roughly three different waves of vertical specialization in the world economy. The first wave was in the 1970s which involved almost all developed countries (86 per cent of the country-year observations) and most countries in East and South Asia (81 per cent) and in sub-Saharan Africa (64 per cent) that are in the dataset. The second wave started in the second half of the 1980s (1986–1994) and was more widespread, now also involving many countries in South America (82 per cent) and Central America (61 per cent). It was followed by a third wave (1995–2008) with a concentration of the VS process. As shown in Figure 15.1, the global VAX-D ratio continued to drop, but this was due to a rapid decline in a smaller set of countries than before: the share of country-years in VS dropped from 62 per cent during 1986–1994 to 57 per cent during 1995–2008. Developed countries were still heavily involved, but there was a sharp drop in the share for East and South Asia (from 69 per cent to 44 per cent) as well as for South America and Central America. Countries in Eastern Europe and Central Asia became more involved however, as the share increased from 54 per cent to 64 per cent. Countries in the Middle East and North Africa experienced relatively few periods of VS with shares well below 40 per cent in any period.

### 15.3.4 Trend 4: Country Heterogeneity in Vertical Specialization Trends

As shown in Table 15.1, most countries initiated a period of vertical specialization, increasingly relying on imports to produce their exports. It is sometimes hypothesized that a period of vertical specialization is followed by a period of vertical integration as a country successfully develops capabilities for domestic production of intermediates. China is often cited as a prime example of this development pattern, interpreted as an indication of its industrial upgrading process (see, for example, Kee & Tang 2016 and Brandt et al. 2017). Vertical specialization followed by vertical integration might be a more general phenomenon for countries that become richer, related to the finding of Imbs & Wacziarg (2003) that over the course of development the production structures of countries first concentrate and later on diversify such that a larger share of inputs can be sourced domestically. Pahl & Timmer (2019) test whether this reversal is found more generally across countries. To do so, they trace for each country that initiated a period of VS (as defined using the Bai & Perron (1998, 2003) tests for structural breaks) whether this trend continued afterwards (the VAX-D trend is strictly monotonic), whether it was followed by a period with a non-significant trend in the VAX-D ratio (the trend is monotonic), or whether it was followed by a period with a significant positive trend in the VAX-D (the trend is non-monotonic).[22] The number of countries that fall into these three bins are given in columns (2)–(4) of Table 15.2. Column (1) indicates the number of countries in each region that initiated VS (repeating column 2 of Table 15.1 for convenience).

Table 15.2**: Number of countries by trend in VAX-D ratios**

| Country group | (1) = (2)+(3)+(4) | Trend in VAX-D ratio: Strictly monotonic (2) | Monotonic (3) | Non-monotonic (4) |
|---|---|---|---|---|
| All countries | 79 | 31 | 23 | 25 |
| Developed | 18 | 11 | 4 | 3 |
| Developing | 61 | 20 | 19 | 22 |
| | | | | |
| East & South Asia | 10 | 2 | 2 | 6 |
| South America | 8 | 5 | 2 | 1 |
| Central America | 7 | 4 | 0 | 3 |
| Sub-Saharan Africa | 9 | 5 | 1 | 3 |
| Mid. East & N. Africa | 9 | 1 | 5 | 3 |
| Eas. Eur. & Centr. As. | 18 | 3 | 9 | 6 |

Note: Each country covered in the table had at least one period with a significant decline in the VAX-D ratio (VS). If the following years are also in a period of VS (i.e. declining VAX-D), then the trend is classified as 'strictly monotonic'. When it is followed by a period with a significant upward trend in the VAX-D ratio then it is classified as 'non-monotonic'. Otherwise it is classified as 'monotonic'.

Source: Data taken from Pahl & Timmer (2019).

The main finding from Table 15.2 is that vertical specialization is often not strictly monotonic: of the seventy-nine countries that initiated VS, only thirty-one had strictly monotonic trends with twenty-three having monotonic trends, and twenty-five countries having non-monotonic trends. The number of countries with non-monotonic trends is relatively high

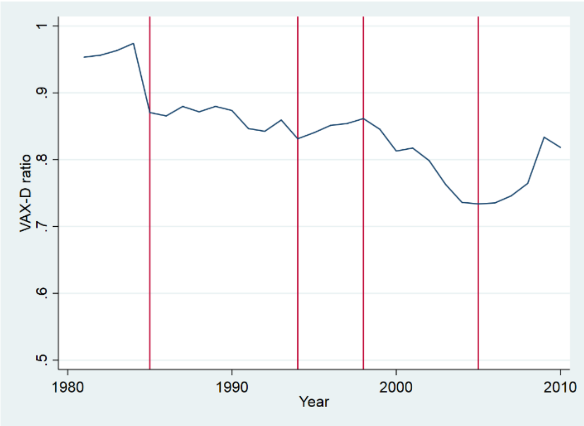
[22] The periods considered are in principle five-year periods, but might be shorter in case no break point could be detected in the time-series for a country (for more details see Pahl & Timmer (2019)).

in the group of developing countries. In particular, we find such non-monotonic patterns in East and South Asia, where six out of ten countries experience non-monotonic patterns. There are also six (out of eighteen) countries in Eastern Europe and Central Asia with upward trends in VAX-D. The upward trends in VAX-D ratios often appear in the mid-1990s.

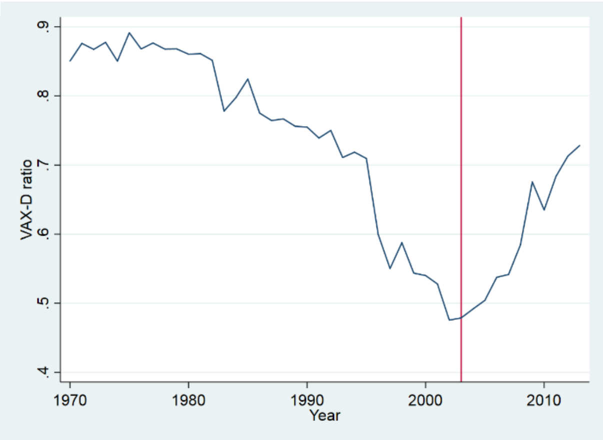
Figure 15.3 depicts the VAX-D ratio for manufacturing exports from four countries, based on the data from Pahl & Timmer (2019), to illustrate the variety in development patterns. China is often singled out as a chief example of a country with a non-monotonic VS development. The rise of China as a prime location for assembly activities was boosted by its accession to the WTO in 2001. China relied heavily on processing trade, with firms importing the major parts and components—typically with tariff exemptions and other tax preferences—which they then assembled, before exporting the finished products. Koopman et al. (2012) found that in 2002, the share of domestic value added in Chinese exports of electronics and computers was only 19.3 per cent. For all manufacturing exports, the share was 50 per cent in 1997 and 2002, increasing to 60 per cent in 2007 (see also Duan et al. 2018). This suggested that China gained the capabilities to substitute imported intermediates by domestic products, taking over more advanced production activities. Kee & Tang (2016) and Brandt et al. (2017) provide further firm-level evidence for this process of upgrading. Figure 15.3(a) depicts the VAX-D ratio for manufacturing exports from China based on the data from Pahl & Timmer (2019). It shows a trend reversal in 2005 when a period of decline in the ratio that began at the end of the 1990s was followed by an upward swing, with the increase being 0.084 points over the period 2005–2010, of which 0.082 points is due to the substitution of domestic for foreign intermediates (see Pahl & Timmer (2019) for more information). This evidence fits the narrative of local firms in China beginning to specialize in the assembly of imported materials in the 1990s, providing them access to markets and technology. Gradually, some firms took over more upstream production stages, building upon domestic learning and innovation, and thereby decreasing their dependence on imported intermediates.

**Figure 15.3** Country examples of trends in VAX-D ratio

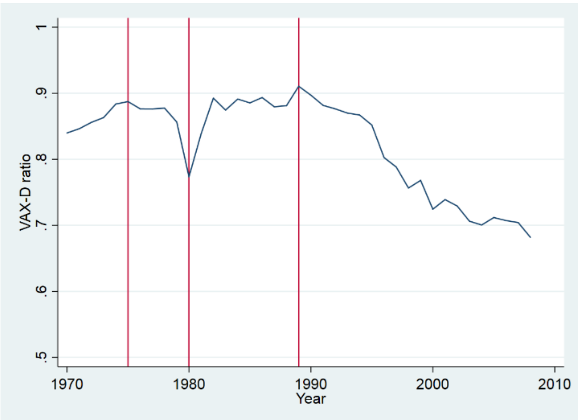
*(a) China*



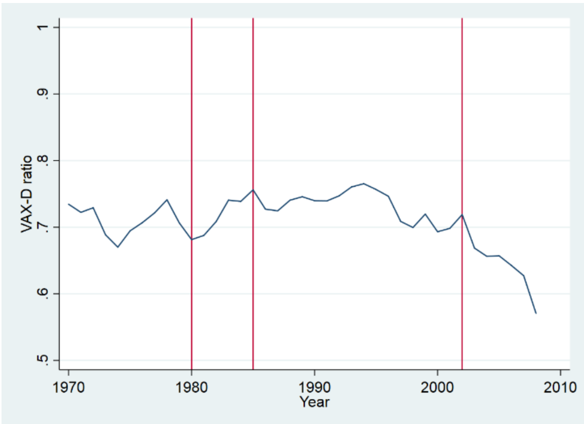

*(b) the Philippines*




*(c) Poland*




*(d) South Korea*




Note: Vertical lines indicate break points (Bai and Perron, 1998; 2003).
Source: Pahl and Timmer (2019).

As another example, Figure 15.3b shows that the Philippines also had a long period of vertical specialization, followed by a strong increase in the VAX-D ratio after 2003, which was mainly due to the substitution of intermediate inputs towards domestic sources. Yet, a reversal in VS is not a necessary correlate of faster growth. Two examples are shown in Figure 15.3:

South Korea and Poland. Neither of them featured an upward trend in VAX-D ratios (except Poland in the early 1980s), yet both transitioned into middle- or high-income status by the end of our time series. In a formal regression analysis, Pahl & Timmer (2019) correlate VAX-ratios with GDP per capita, time dummies, and a host of control variables. They conclude that the VAX-D ratio is negatively correlated with GDP per capita. In particular, they do not find evidence for a U-curve relationship, even when restricting the sample to developing (non-oil and non-OECD) countries. At best, there is some weak evidence that the negative slope flattens out at higher levels of income. On average, countries do not reverse the VS process over the course of development.

This raises an important and more general question: how may participation in global value chains (GVCs) contribute to a country's development path? Pahl & Timmer (2020) use new data to measure the level of employment (i.e. number of workers) and productivity (i.e. value added per worker) that is related to manufacturing exports for a set of fifty-eight countries for the period 1970–2008. In an econometric exercise, they show that vertical specialization in the production of manufacturing exports is positively associated with productivity growth in the manufacturing sector. A one per cent increase in vertical specialization is associated with a 0.02 percentage point increase in the growth rate of productivity. This is economically meaningful: if a country increases its vertical specialization from the 25th to the 75th percentile, this translates into a 1.6 percentage point higher growth rate, which is significant in the context of a mean growth rate of productivity in the sample of around 7 per cent. This finding is particularly interesting for developing countries as the marginal effect is bigger for countries further from the productivity frontier, a finding related to that of unconditional convergence in manufacturing by Rodrik (2013). In the case of employment, however, the findings of Pahl & Timmer (2020) provide a more pessimistic outlook. They find that the association between VS and employment growth is not statistically different from zero, with the coefficient even being negative. This negative effect is stronger for countries further from the productivity frontier. Hence, on average, developing countries do not seem to benefit from vertical specialization in employment terms.

These findings are in line with analysts who are sceptical about the potential for job growth through GVC participation. In a recent paper, Rodrik (2018) hypothesizes that GVC production technology is biased against unskilled workers, muting the prospect of job growth for poor countries. To test this, Reijnders et al. (2016) estimated the bias in technical change in GVC production through an econometric analysis of GVC cost functions. They find that technical change in GVCs was strongly biased against the use of low-educated workers, being neutral for middle-educated workers and biased in favour of high-educated workers. They show that the biases indeed moderate the potential of GVCs to increase the demand for low-educated workers in poor countries. These results do not preclude the possibility, however, that some countries have successfully relied on GVC production as a stepping-stone for both productivity and employment creation: GVCs allow for a finer division of labour, with firms carrying out a limited set of tasks, while importing the required inputs, services, and know-how. At the least, GVC participation eases entry into global markets such that poor countries can develop comparative advantage on a larger scale. How to realize the potential from GVC participation is therefore high on the international development policy agenda (see, for example, World Bank 2020 and references therein).

# 15.4 Functional Specialization in Trade

## 15.4.1 Towards Functional Specialization in Trade

With cross-border production sharing, countries can specialize in various stages of the production process. While the measure of vertical specialization discussed in the previous section is informative of a country's involvement in global production networks, it is silent on the characteristics of the tasks carried out within this network. For example, a low domestic value added to gross export ratio may reflect specialization in low-tech activities in the final stage of production, such as assembling a laptop out of imported complex components. Yet, a country that specializes in high-tech activities such as assembling an engine out of imported parts and putting it in an imported car body might also have a low value added to gross export ratio. Moreover, a country can specialize in trade without importing. Suppose that a country (say Germany) initially produces cars at home, carrying out all stages of production. Then it starts to export car parts to Slovakia say, where these are assembled into final products and subsequently exported. In this case, Germany is specializing in a particular upstream stage of production, yet this will not be revealed in the German vertical specialization measures: the share of domestic value added in German exports remains unity. Information on the type of activity—or tasks—carried out is needed to understand changes in the production structure of a country and its role in global production networks.

Table 15.3 provides an illustrative example taken from Timmer et al. (2019).[23] It reports variants of Balassa (1965) RCA indices in exports of electronic goods for a select group of countries. Indices above 1 reflect specialization and are shown in bold. China, Hungary,

[23] This section relies heavily on the data and analyses presented in Timmer et al. (2019) and the reader is referred to this work for further findings and discussion.

Mexico, and Japan appear to have a comparative advantage in exports of electronics based on gross export flows (column (1)). Yet, column (2), which uses data on the value added in exports, reveals that Hungary and Mexico actually do not have a comparative advantage in the production of electronics for exports, while the United States does. This is because the former countries rely much more on imported intermediates to produce for export than the United States. Using the functional specialization perspective reveals new and surprising insights. Based on statistics that report on the occupation of workers, we measure the value that is added by workers carrying out particular functions, as discussed in Section 15.2. Columns (3)–(6) show that Mexico and Hungary do have a comparative advantage in electronics production after all, but only in carrying out fabrication activities. The comparative advantage of China is in fabrication as well as marketing activities. The United States and Japan are specialized in R&D and marketing activities associated with orchestrating and governing global networks of production. This example illustrates that the functional specialization approach is not only conceptually appealing, but can also be fruitfully applied in empirical work and is able to uncover new patterns of specialization.

**Table 15.3: Indices of specialization in exports of electronic goods, 2011**

| Exporting country | Based on gross export value | Based on value added | Based on value added in functions | | | |
|---|---|---|---|---|---|---|
| | | | Fabrication | R&D | Management | Marketing |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| China | **2.56** | **2.57** | **4.02** | 0.85 | 0.80 | **2.19** |
| Hungary | **1.60** | 0.97 | **1.20** | 0.83 | 0.70 | 0.97 |
| Mexico | **1.54** | 0.86 | **1.83** | 0.90 | 0.78 | **1.12** |
| Japan | **1.38** | **1.57** | **2.06** | **1.49** | 0.35 | **1.91** |
| United States | 0.90 | **1.05** | 0.59 | **1.50** | **2.36** | **1.23** |

Notes: Balassa indices based on comparing shares of electronics in exports of a particular country with the same share for all countries in the world. Exports of value added include value added by any industry in the export of goods from the electronics industry (ISIC rev. 3 industries 30 to 33). Indices greater than one are in bold.

Source: Data are from Timmer et al. (2019), Table 1.

### 15.4.2 Functional Specialization in Exports: Global Trends

We elaborate upon the data from Timmer et al. (2019) to show the global trends in functional specialization in trade. Table 15.4 shows the value added in exports for a group of twenty-one advanced countries and a group of other countries in the world. Exports refer to all exports of a country, including exports of goods as well as of services (in contrast to Section 15.3 in which we analysed exports of manufacturing goods only). Three characteristics of the global system of production stand out. First, there has been a massive shift in the location of production for export away from the group of advanced countries to the group of other countries. In 1999, the value added in exports by advanced countries was almost three times that of value added by other countries in their exports.[24] By 2011, this gap had considerably narrowed.

**Table 15.4: Value added in exports by advanced and other countries in the world**

| | Value added in exports by advanced countries | | Value added in exports by other countries | |
|---|---|---|---|---|
| | 1999 | 2011 | 1999 | 2011 |
| Domestic value added (billion US$) | 3,431,667 | 7,189,636 | 1,218,470 | 5,891,455 |
| Share of labour | 63.1% | 61.4% | 43.3% | 38.8% |
| Share of capital | 36.9% | 38.6% | 56.7% | 61.2% |
| | | | | |
| Labour income in exports (billion US$) | 2,166,980 | 4,412,770 | 528,105 | 2,283,277 |
| Fabrication share | 34.8% | 28.8% | 47.3% | 44.8% |
| Management share | 16.1% | 18.1% | 16.1% | 14.3% |
| Marketing share | 33.4% | 35.1% | 27.9% | 28.5% |
| R&D share | 15.7% | 18.0% | 8.7% | 12.4% |

Note: advanced countries are the fifteen countries that joined the European Union before 2004 plus Australia, Canada, the United States, Japan, South Korea, and Taiwan. Other countries refer to all other countries in the WIOD database, including a rest-of-the-world region.

Source: Own calculations based on data from Timmer et al. (2019).

[24] These value-added measures do not suffer from a double counting problem in the case of intermediates exports that are used by another country to produce for exports. This is in contrast to measures based on gross exports which do suffer from double counting in this case (see discussion in Los & Timmer 2018).

Second, the share of capital income in exports by the other non-advanced countries is high and increasing over time. Value added consists of compensation for workers (i.e. labour income) and a gross operating surplus (i.e. capital income, which is calculated as a residual here by subtracting labour income from gross value added). Capital income accrues as income to the owners of capital assets: traditional tangible (physical) assets as well as intangible assets such as patents, designs, software, databases, and brand names which are increasingly important in a modern economy (Haskel & Westlake 2017).[25] In 1999, capital was already capturing 57 per cent of the value added in exports by the other countries, increasing to 61 per cent in 2011. A substantial part of this income is likely to flow out of these countries. The emergence of global production chains involved sizable flows of cross-border investment, and part of the generated value added will accrue as capital income to multinational firms. The residence of the ultimate recipients of this income is notoriously hard to track, not least because of the notional relocation of profits for tax accounting purposes (Lipsey 2010; Guvenen et al. 2017). In contrast to capital income, labour income is much more likely to remain in the region as workers typically reside close to the location of production. In 2011, total income for workers involved in exports of advanced countries was almost double that of workers involved in exports by the other countries, although obviously this gap is also rapidly declining.

A third observation from Table 15.4 relates to the pattern of functions that the countries carry out. Note that this pattern is based on income shares of various groups of workers (characterized by their occupation) in the production for exports. The activity of workers can easily be described using their occupations as discussed in Section 15.2 of this chapter. Yet this is much more difficult for capital assets: for example, a computer can be used for fabrication as well as for knowledge-intensive activities. Moreover, most intangible assets are produced by knowledge workers such that there is an intertemporal link between labour and capital incomes.

[25] See also Chen et al. (2018) for a quantification of the income of intangibles in GVCs.

For these reasons income for functions is only tracked for workers. Table 15.4 shows that the share of fabrication activities in advanced countries is much lower than in the other countries, with the declining trend for advanced countries also being more rapid than for the other countries. Such results suggest that advanced economies continued to specialize in headquarter activities, while moving out of fabrication activities.

### 15.4.3 Idiosyncratic Specialization Patterns

One of the most surprising findings in Timmer et al. (2019) is the large heterogeneity in specialization patterns, even across countries at comparable levels of development. The aggregate trend presented in Table 15.4 hides substantial variation across countries. This is illustrated in Figure 15.4 which plots GDP per capita against the functional specialization (FS) index for forty countries for the year 2011, with a separate scatterplot reported given for each of the four different functions.[26] The horizontal lines separate country observations with FS indices below and above 1. Panel (a) shows a clear correlation between GDP per capita and specialization in R&D activities (with a Pearson correlation of 0.63). In 2011, most advanced economies had a clear comparative advantage in R&D activities. This pattern is much less clear for the other headquarter activities though. Panels (b) and (c) show FS indices in marketing and management activities respectively. While the correlation with GDP per capita is positive, it is much less strong, being just 0.13 for marketing and 0.30 for management. Considering these two panels further, we see the heterogeneity in specialization patterns across countries more

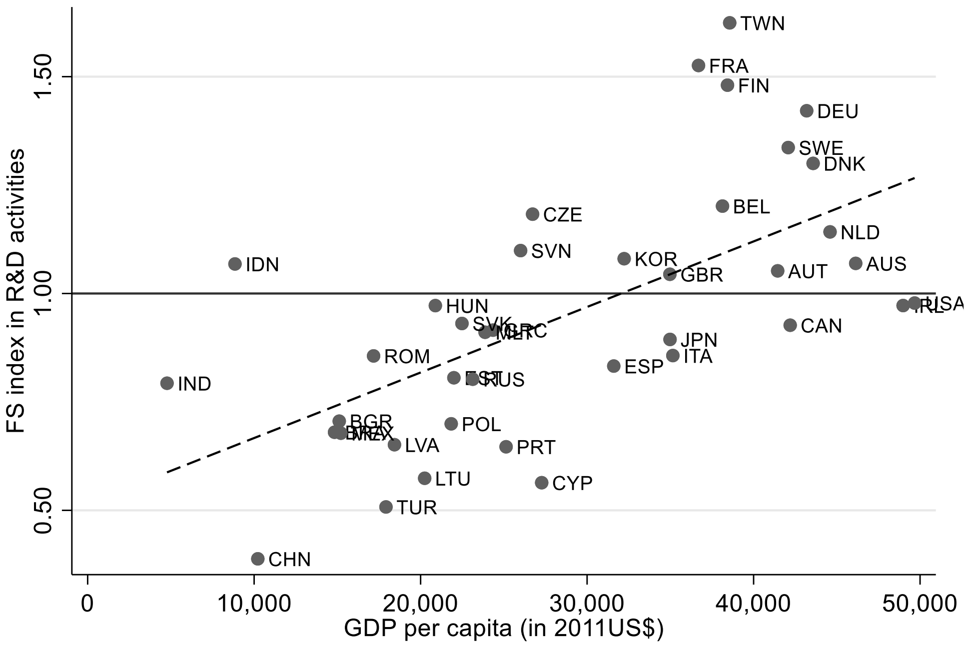
[26] Note that the set of countries is much smaller than in the previous section. In particular, the sample contains mostly high-income and fast-growing emerging economies. As yet, there is little information on the functional specialization patterns of poor countries, an important area for future research.

clearly, For one group of countries—including Belgium, Ireland, the Netherlands, Spain, and the United States—we observe a comparative advantage in both marketing and management, while for a second group—including Austria, Canada, Denmark, Japan, Italy, South Korea, and Sweden—we observe a specialization in marketing activities only, with a third group—including Finland, France, and the United Kingdom—specialization is found in management activities only. Not surprisingly, specialization in fabrication activities is negatively related with income per capita (with a Pearson correlation of –0.55), as shown in panel (d) of Figure 15.4. The income share in exports from fabrication activities in China is estimated to be about 63.4 per cent in 2011, by far the highest in the full set of countries, meaning that headquarter activities are relatively unimportant. This is further confirmed by the FS indices for R&D, management and marketing in the case of China, which were respectively 0.39, 0.30, and 0.77 in 2011, indicating a lack of specialization in these activities.[27] India has a much smaller share of fabrication activities in its exports. The Indian economy is well known for its stunted industrial development, characterized by a high share of small-sized firms. Firm owners are also classified as managers which drives up the FS index for management.

[27] It should be noted that the FS index is a relative measure: it is based on a comparison of value added across various activities within a country and is silent on the overall level of activity in a country. It has therefore to be interpreted in conjunction with other information on volumes of trade. In the case of China, the income generated in the headquarter activities has rapidly increased, yet fabrication activities were growing just as fast such that the FS index of R&D, which is stated relative to other functions, remains low.

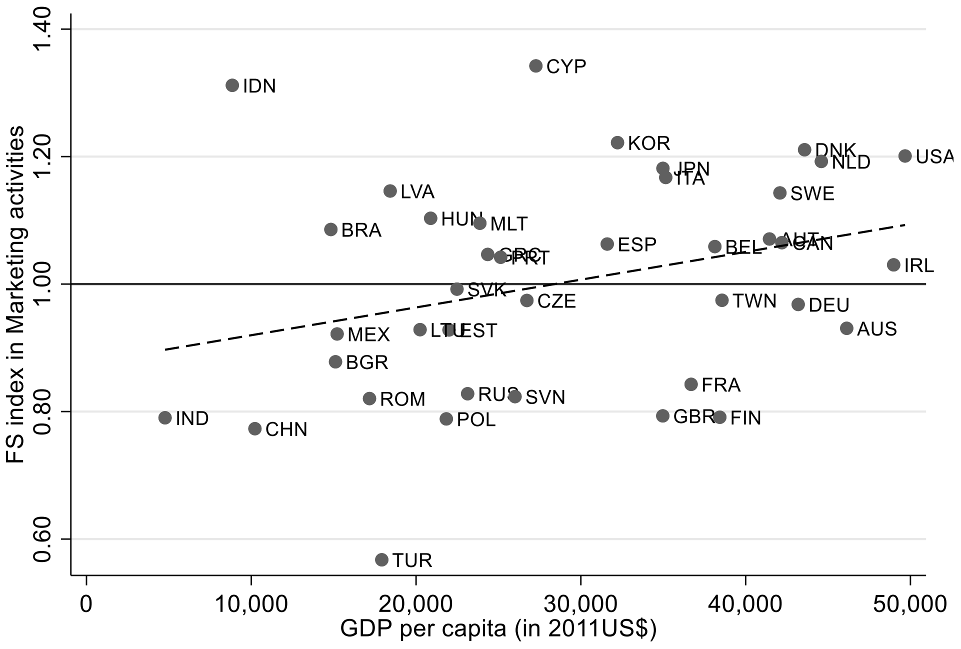
**Figure 15.4 Functional specialization in exports, 2011**

a. R&D



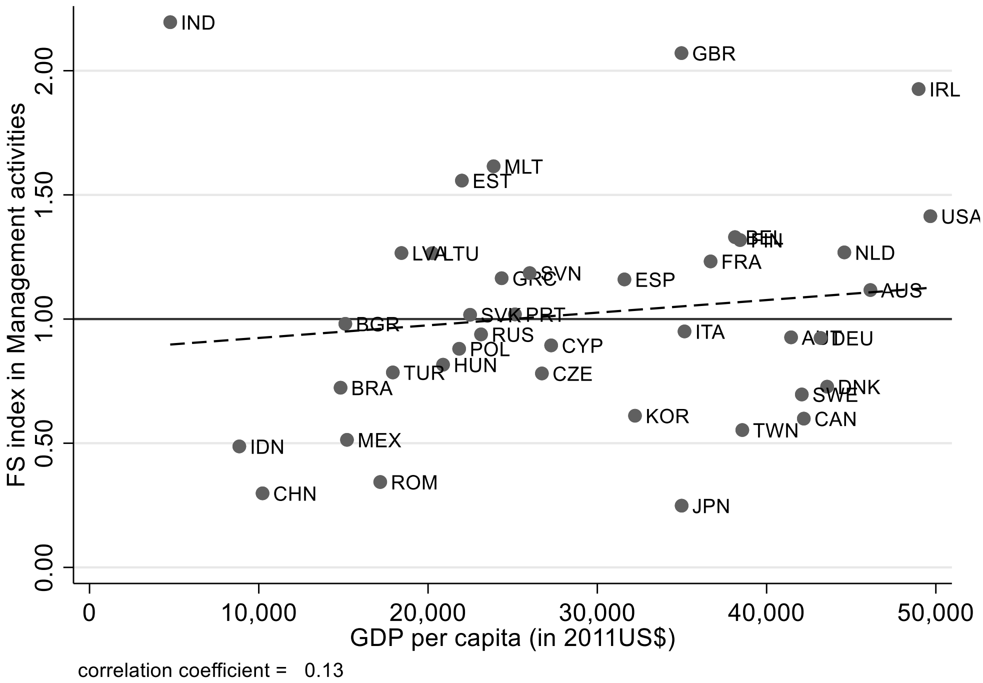

correlation coefficient = 0.63

b. Marketing

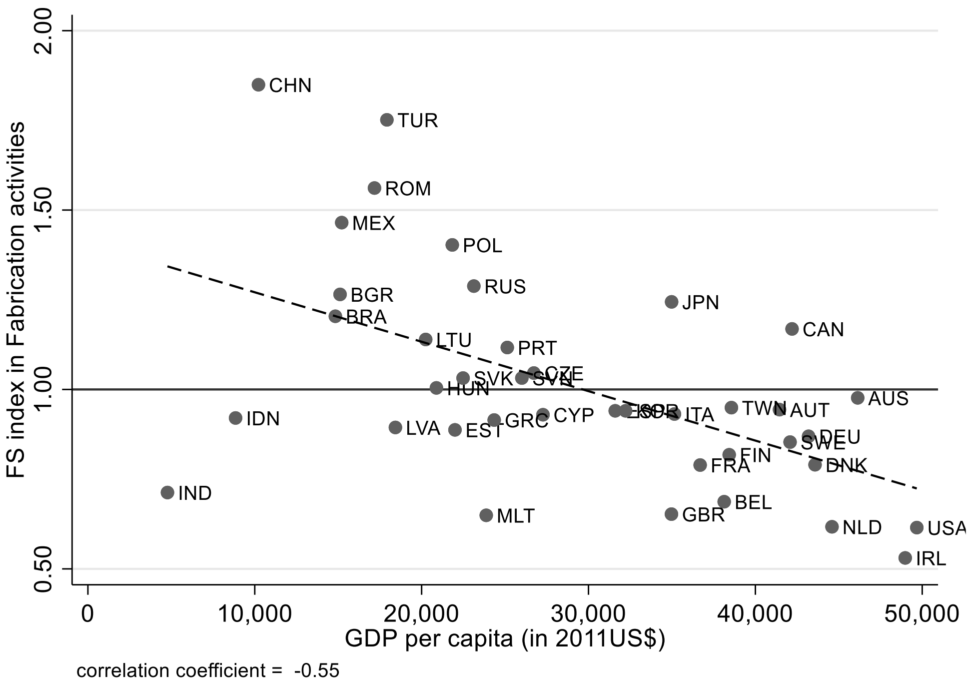



correlation coefficient = 0.31

c. Management




d. Fabrication




*Note*: Countries above the horizontal line indicate specialization in a function (FS index ≥1). This figure is reproduced from Timmer et al. (2019), Figure 3.

These findings suggest that there are many idiosyncratic determinants of a country's specialization pattern beyond its general development level. All advanced countries have well-functioning legal systems, high-quality infrastructure, and in general high levels of human capital. Differences in specialization must be driven by other characteristics such as the size of the country, the attractiveness for multinational headquarter location, geographical characteristics, as well as historically developed capabilities and networks. Timmer et al. (2019) find that transformation in specialization patterns can be rapid though, with various countries in Central and Eastern Europe having developed new specialization patterns within the decade, graduating from specialization in fabrication towards specialization in R&D (Czech Republic), management (Slovenia), or marketing (Hungary). The importance of local conditions is stressed in the theory on global production networks articulated by Dicken et al. (2001), Henderson et al. (2002), and further developed in Coe et al. (2008) and Coe & Yeung (2015). Dosi & Tranchero (Chapter 19) in this volume provide a discussion of the evolutionary microeconomic theory of innovation and production, showing how firm behaviour and learning is embedded in broader national systems of innovation.

## 15.5 Concluding Remarks

This chapter provided an overview of vertical specialization in trade for a large set of countries since 1970. It distinguishes three waves of vertical specialization in the world economy using new data on the domestic value added in a country's exports. The first wave was in the 1970s, involving most developed countries and various countries in Asia as well as in sub-Saharan Africa. The second wave (1986–1994) was more encompassing as the process of international production fragmentation spread to countries in South and Central America. In the third wave (1995–2008) the process intensified further, also spreading to Eastern Europe, but at the same time concentrating in a smaller set of less developed countries in Asia, most notably China.

Countries participating in global production networks export a bundle of activities, some of which are carried out locally and others imported in embodied form. As a result, countries (or other geographical units) are competing in tasks rather than products in a process of functional specialization.

We demonstrated the potential for the measurement of functional specialization using new data on occupations to characterize domestic activities that add value in export production. We showed a strong international division of labour with advanced countries specializing in headquarter activities (R&D, marketing, and management) and other countries specializing in fabrication activities. There is a strong correlation between GDP per capita levels and specialization in R&D activities (positive) and in fabrication activities (negative), while the correlation for marketing or management activities is weak. There is also a great deal of heterogeneity in specialization patterns, even across countries at comparable levels of development. Taken together these findings are suggestive of the importance of other determinants of comparative advantage alongside standard Heckscher-Ohlin differences in factor endowments.

The functional specialization of a country is likely to depend on particular externalities within and across functions. For example, Defever (2006, 2012) emphasizes the impact of complementarities between R&D and fabrication activities that are carried out in one location, and discusses other motives for the co-location of activities. He finds that market access motives are an important driver for the location of sales and marketing activities close to end-consumers. Coe & Hess (2005) discuss the important role of transnational retailers in creating new supply network structures, suggesting intricate links between the location of marketing, management, and fabrication functions across regions. Gereffi (1999) shows how large retailers manage global production systems of textiles and govern the distribution of value along the chain. The role of the distribution sector is generally ignored in empirical trade-in-value-added studies which focus exclusively on production stages and novel work is needed here. Obviously, externalities go beyond traded input–output relationships, as they typically involve non-recorded knowledge flows that are tacit and intangible. Yet, it seems reasonable to assume that knowledge flows are positively related to physical trade flows and, more generally, to GVC participation. The functional specialization approach based on information from input–output tables is therefore a useful place to start a quantitative analysis.

We believe that the new type of empirical analysis presented in this chapter opens up avenues to better articulated theories of structural change and trade that are centred on tasks and activities rather than on products or industries. Conceptually, it suggests that theories of structural change in which (the structure of) demand plays a major role can no longer rely on a simple one-to-one mapping of consumption to production. Consumption (or exports) of manufacturing goods induces value-added generation in both manufacturing and non-manufacturing sectors (see also Duranton & Puga, 2005; Herrendorf et al. 2014). Moreover, technological change appears to be biased towards particular tasks, rather than particular sectors of the economy. Autor et al. (2003) put forward the 'routinization hypothesis' which states that new information technology capital complements workers engaged in abstract tasks, substitutes for workers performing routine tasks, and has little effect on workers performing manual and services tasks. This hypothesis has been corroborated by Goos et al. (2014) for a large set of advanced countries. Reijnders & de Vries (2018) provided wider evidence that suggests that this also holds for production in less advanced countries. Acemoglu & Autor (2011) provide a rich task-based model to explain the recent changes in earnings and employment distribution dynamics in advanced countries. In this model, the assignment of skills to tasks is endogenous and technical change may involve the substitution of machines for certain tasks previously performed by labour. Offshoring is modelled analogously as the substitution of tasks carried out by domestic factors for imports. Extending this type of modelling to GVCs, through characterizing imports by the foreign factors that were needed to produce it, will be an interesting avenue for future research.

The process of functional specialization also has implications for analyses of development paths and industrial upgrading. In an influential paper, Hausmann & Rodrik (2003) argue that products differ in their potential for productivity growth, for example, through differences in learning-by-doing and technical trajectories. Export specialization patterns that are geared towards so-called high-productivity goods appear to be a determinant of subsequent growth (Hausmann & Rodrik 2003, Rodrik 2006; Hausmann et al. 2007). Moreover, these studies found that countries typically develop comparative advantages in products that are closely related to those they are currently already strong in. As a result, the position of a country in the so-called product space matters for development opportunities, and lock-in in sub-optimal equilibrium is possible (Hausmann & Hidalgo 2011). This type of analysis has become popular in assessments of a country's growth potential and used to inform trade and industrial policies (Hausmann et al. 2013). However, in a world with production fragmentation it does not matter what you export, but what you do in exporting. Industrial upgrading can best be characterized as a process of functional upgrading in GVCs in the tradition of Gereffi and followers (Gereffi 1994, 1999). Central in this line of the literature is the role of multinational enterprises in governing the plethora of activities in the network, both intra- and inter-firm (Gereffi et al. 2001, 2005).

Can we expect functional specialization measures to become a standard tool for economists in due course? Ongoing efforts in the international statistical community aim to improve data sources underlying trade-in-value-added statistics and to institutionalize their production in regular statistical programmes. In the short run this involves mixing existing firm-level production data and firm characteristics (such as firm size, ownership, and export status). In the longer run this would entail the development of common business registers across countries, increased data reconciliation, and new data collections on value chains beyond counterparty transactions (Landefeld 2015). Promising in this respect is the development of firm-level surveys that track offshoring of business functions in Europe (Nielsen 2018). These are all steps in the right direction, yet it should be emphasized that this line of work is still in an early phase. All in all we believe that we can considerably improve our understanding of structural change in trade through combining insights from the standard product-level trade statistics with the insights from composite measures of value added and functional specialization in trade presented in this chapter.

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# Appendix

**Table A15.1: World VAX-D ratio for exports by manufacturing industries**

| Exporting industry | ISIC rev. 3 | 1970 | 1980 | 1986 | 1995 | 2007 | 2013 |
|---|---|---|---|---|---|---|---|
| Food | 15t16 | 0.85 | 0.82 | 0.84 | 0.81 | 0.79 | 0.77 |
| Textiles | 17t19 | 0.87 | 0.83 | 0.83 | 0.78 | 0.75 | 0.75 |
| Wood | 20 | 0.89 | 0.85 | 0.86 | 0.81 | 0.77 | 0.74 |
| Paper | 21t22 | 0.89 | 0.85 | 0.85 | 0.83 | 0.77 | 0.74 |
| Petroleum | 23 | 0.72 | 0.60 | 0.74 | 0.69 | 0.65 | 0.57 |
| Chemicals | 24 | 0.87 | 0.78 | 0.80 | 0.78 | 0.68 | 0.65 |
| Plastic | 25 | 0.88 | 0.83 | 0.81 | 0.76 | 0.71 | 0.69 |
| Mineral | 26 | 0.89 | 0.84 | 0.86 | 0.84 | 0.79 | 0.76 |
| Metal | 27t28 | 0.88 | 0.85 | 0.84 | 0.81 | 0.73 | 0.72 |
| Machinery | 29t33 | 0.92 | 0.88 | 0.86 | 0.76 | 0.69 | 0.70 |
| Transport | 34t35 | 0.87 | 0.86 | 0.81 | 0.75 | 0.69 | 0.68 |
| Other | 36t37 | 0.89 | 0.86 | 0.85 | 0.80 | 0.75 | 0.75 |

Note: World VAX-D ratio is the sum of VAX-D across seventy-four countries divided by their sum of gross exports.

Source: Table taken from Pahl & Timmer (2019).