Economic Development under Global Production Fragmentation: Value Added in Exports of 93 Countries between 1970 and 2008

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Abstract

How can countries benefit most from the new opportunities of production sharing in global value chains? Should countries indeed specialize in a subset of production stages or should they aim at expanding the range of stages preformed domestically? Based on a novel methodology to approximate the share of domestic value added in gross exports (DVAX ratio), this paper constructs data for a set of 93 countries with 19 sectors between 1970 and 2008. This methodology circumvents the need of input-output tables and therefore allows for a wide application across countries and time. Based thereupon, first results show a negative correlation between the initial level of the DVAX ratio and subsequent growth of value added in exports. This suggests that countries that endorse foreign intermediate suppliers and specialize in a smaller range of production stages tend to gain more in terms of domestically captured value added.

JEL-Classification: F13, F14, F15, F63

Keywords: Economic Development, Global Value Chains, International Trade

I. Introduction

Global production fragmentation has altered the nature of industrial production. While complete final goods used to be produced within national borders, it is now a global and interconnected process (e.g. Baldwin, 2006). This has implications for development strategies. Up until now, industrial policy and development theory has been based on the presumption that industries are domestic and exports the reflection of domestic production factors and industrial capabilities. Production sharing in global value chains (GVCs) opens new venues to join and restructure manufacturing value chains, which may provide new and easier ways to industrialization than the paths taken by Japan or South Korea. But how to benefit most from this production sharing and what is the role of industrial policy?

Long-term studies linking production fragmentation and development strategies are rare (for a recent appraisal, e.g. Taglioni and Winkler, forthcoming), which is partly due to limited data availability. The calculation of key indicators of production fragmentation requires input-output tables, which are published by only a subset of countries whose statistical offices have sufficient capacities. To extend the analysis to the developing world and to allow for a long-term view on production fragmentation, this paper proposes a methodology to approximate these measures and that circumvents the need of input-output tables. Second, it harmonizes and combines available data series and applies this method to construct a data set of 93 countries with 19 sectors (14 manufacturing) between 1970 and 2008.[1] Third, equipped with this data set, first results are provided on whether specializing in a subset of production stages is associated with higher growth rates of domestic value added in exports.

The manufacturing sector is argued to be one of the main drivers of economic development, but only few countries managed to build up a considerable manufacturing base (e.g. Rodrik, 2015; McMillan et al., 2014; Felipe et al., 2015, Szirmai, 2012). These few countries supplied most of the world's demand for manufactured goods and the remaining countries had only a small manufacturing base as they were not competitive enough to meet international standards (Baldwin, 2013). In a world with fragmented production, it is now possible to offshore the production stages in which a country has a comparative disadvantage and only focus on the remaining ones. Using foreign intermediates in the production of exports is thus argued to increase export competitiveness, which, in turn, increases exports. This output expansion is expected to be large enough to compensate for the loss of value added that is due to the replacement of intermediate suppliers, and thus, it is expected to be associated with a net gain in terms of value added (e.g. Baldwin, 2012; Taglioni and Winkler, forthcoming). This, however, is only true if the output expansion is indeed large enough to compensate for the value-added loss due to substituted upstream suppliers. In that regard, it is argued that increased export competitiveness alone is not enough. To assure that domestic value added is growing, countries must

[1] This is the current version of the data set. Bolivia, Venezuela, United Kingdom, Italy, Botswana, Ethiopia, Malawi, Tanzania, Hong Kong and Taiwan are planned for inclusion, and it will be extended to cover 1963 to 2015.

also focus on capturing a larger share of value added per unit of exports, i.e., integrate domestic intermediate suppliers and perform a larger range of production stages (e.g. Dalle et al., 2013; Milberg et al., 2014; Rodrik, 2013b). This paper investigates this direct effect of production fragmentation. Is value added generated in the production of exports indeed growing faster if a country specializes in a subset of production stages and imports the remaining intermediates?

To study such questions, this paper constructs the well-known measure of "vertical specialization" (e.g. used in Hummels et al., 2001; Koopman et al., 2012). This is a ratio that captures how much of the gross export value is added domestically and how much abroad. Here, it is defined as the ratio of domestic value added generated in the production of gross exports over gross exports (DVAX ratio). The lower it is, the more intensively it is made use of foreign intermediates. The literature has started to address the question whether and how global value chains can work for development (e.g. Boffa et al., 2016; Kummritz, 2016; Taglioni and Winker, forthcoming). In that literature, the DVAX ratio is typically seen as a measure of GVC participation and a higher foreign content is argued and shown to be associated with net value-added gains at the economy and industry-wide level. In this paper, it is argued that what matters for industrialization is value added in manufactured exports. Hence, the question is whether the relative domestic contribution to exports is associated with value added in exports rather than the effect of GVC participation on the economy or industry as a whole. The presented correlations indicate that it does indeed matter whether relatively more or less value is added domestically. The results show a negative association between initial levels of the DVAX ratio and growth of value added in exports. This is suggestive that reducing the domestic content, i.e. increasing foreign sourcing, does indeed increase export competitiveness and translates into higher domestic value added. Besides the conceptual difference to the related literature, this paper will be able to exploit differences across sets of countries and time periods by applying the proposed methodology.

This methodology is based on two assumptions. First, it is argued that the distribution of sourced intermediates across supplying industries can be approximated. Hence, it is argued that it is possible to find sets of countries for which a given industry, say Electronics, sources a similar share from each supplying industry. Second, it is argued that there are more and less foreign-penetrated industries, which holds across (sets of) countries. Taking into account the level of imported intermediates and the relative use of total intermediates across using industries within countries, this provides a feasible proxy to distribute imported intermediates across using industries. With these two assumptions, the structure of input-output tables can be approximated. In a controlled setting based on data from the World Input-Output Database (WIOD; Timmer et al., 2015), the validity of the method is shown. Based on regression analysis, the validity is shown at the country level in levels and in differences, as well as at the industry level in levels and in differences. Similarly, spearman rank correlations show that the method reproduces the cross-sectional and time-series properties. To analyze long-term trends and developing countries, it is therefore argued for a hierarchy of data inputs. There is high value added in making use of data series of gross output and value added at the industry level and in reconciling trade flows of intermediate goods. However, for example, it is debatable whether using Mexico's 2003 input-output table to infer sourcing structures in the mid-1970s is superior to relying on a proxy structure combined with carefully collected data on gross output by industry, value added by industry and trade flows of intermediates. To construct the data, it is thus made extensive use of available series of gross output and value added at the industry level and of trade data. It is discussed how the constructed data set compares to the main time-series trends and cross-country properties in existing data sources (e.g. Johnson and Noguera, 2014; Timmer et al., 2015).

The paper proceeds as follows. Section II discusses the role of manufacturing and paths to industrialization with and without global production fragmentation. Section III focusses on the methodology to approximate the input-output indicators, their interpretation and the validation of the method. In section IV, the data sources and the data set are discussed. Section V describes the empirical analysis and discusses the results. Section VI concludes.

II. Manufacturing, industrialization and global production fragmentation

II.A. The primacy of manufacturing

From Britain to East Asia, today's rich countries have all enjoyed a large manufacturing base in terms of output and employment shares and often built this up through manufactured exports (Felipe et al., 2015; Rodrik, 2013 and 2015). This is not only considered to be a mere correlation, but it is argued that a strong manufacturing base and the specialization in manufactured goods precedes growth of per capita incomes (e.g., Felipe et al., 2015; Szirmai, 2012).

Following Lewis (1954), it is argued that shifting resources into manufacturing is associated with a productivity bonus. Average productivity levels in manufacturing are higher than in agriculture, and therefore a shift of resources will induce a positive aggregate effect (see also McMillan et al., 2014; Rodrik, 2013a). This holds also in a dynamic sense as productivity growth rates are also higher in manufacturing than in other sectors: Rodrik (2013b) even shows unconditional convergence of productivity levels in (formal) manufacturing across countries. Hence, the larger a country's manufacturing sector, the faster it catches up with the developed world (Rodrik, 2013b). Relatedly, manufacturing is argued to exhibit stronger opportunities for capital accumulation and economies of scale (Cowen, 2016; Szirmai, 2012).

Manufacturing also favors a strong middle class. Cowen (2016) argues that manufacturing employment is characterized by high returns to experience. A worker cannot be replaced as easily as in low-productivity service jobs (e.g. retail) and employers have an incentive to invest in workers' human capital, which in turn positively affects aggregate growth. Furthermore, manufacturing can absorb a large share of the labor force, as compared to high-productivity services. Supporting sectors are stimulated by linkages of manufacturing. A successful manufacturing firm may spur growth prospects of suppliers of intermediates (Cowen, 2016). Similarly, manufacturing is argued to create positive externalities in the form of investments through linkages to other sectors and through spillovers that operate through disembodied knowledge flows between sectors (Szirmai, 2012).

In a global context, this is supported by manufacturing's tradability. Exporting manufactured goods is a sign that these goods have reached an internationally competitive standard. Cowen (2016) argues therefore that value added created through exports is "real" as it is reflecting real productive advances rather than value added created through government protection. Furthermore, exporting manufactured goods will expand the domestic manufacturing sector, as foreign demand can be supplied. Relatedly, following Engel's law, relative demand for manufacturing goods rises as per capita incomes rise, while agricultural expenditure shares decrease (Szirmai, 2012). Countries specializing in manufacturing goods will therefore benefit from increasing global per capita incomes. Trade may also bring dynamic gains from learning effects and technology transfer (e.g. Keller, 2004; Taglioni and Winkler, forthcoming).

Industrialization and economic development are thus linked to trade of manufactured goods. The next section discusses how global production fragmentation may have made it easier for countries to enter export markets and thus industrialize.

II.B. Industrialization with and without global production fragmentation

Being able to serve global demand for manufactured goods is also a key channel in Baldwin's (2013) framework of industrialization. He argues that industrialization is linked to an interplay of demand and the creation of industrial competencies (i.e., becoming more competitive in manufacturing production). Before the rise of global production fragmentation, industrialization was about becoming competitive in the production of final manufactured goods by building whole supply chains at home. Hence, whether a country was able to export manufactured goods depended on industrial competencies across *all* production stages needed to produce the final good. A country with relatively low industrial competencies was not able to export manufactured goods and if imports were not restricted, also the supply for the domestic market came from abroad. This meant that some countries with the highest industrial competencies became the manufacturing suppliers of the word, while most other countries remained on a low level. In 1970 for example, 70% of world manufacturing value added was generated in the G7 countries (Baldwin, 2013). Other countries caught up only slowly, which, according to Baldwin (2013), is because industrial competencies are built up by demand for manufactured goods themselves. Hence, if there is no demand for a country's manufactured goods (because manufacturing is not competitive), there will be no creation of industrial competencies and vice versa. Early industrializers thus enjoyed a comparative advantage in manufacturing for a relatively long period before other countries were able to catch up. And they were not able to catch up without government response. The main idea was to provide a push for a country's industrial competencies until it was competitive enough to serve the global market. After that point, demand for the country's goods would foster the creation of industrial competencies itself. To reach that point, one strategy was to protect the domestic market so that domestic industry could serve domestic demand in the hope that it would eventually become competitive enough to survive without protection (import-substitution industrial policies). The second strategy was to subsidize and incentivize export production until it could supply the world market without the state's help (export-oriented strategies). The latter coined the term export-led growth and was mainly successful in East Asia (on South Korea, e.g., Magaziner and Patinkin, 1989). [2]

To take part in export markets today, a country does not have to perform all production stages needed to produce the final good anymore. The "second unbundling" was induced by reductions of information and communication costs and made it possible to fragment production processes into fine-grained production stages across countries (Baldwin, 2006). This implied that specialization patterns moved from the level of the final good to the level of production stages (e.g., Baldwin and Venables, 2013).

Be it a final good or an intermediate input, a country's production can nowadays become more competitive if it concentrates on the production stages in which it has a comparative advantage, but offshores the ones with a comparative disadvantage. This is praised as an easy entry into manufactured export production. Reducing the domestic contribution to the production stages in which a country has a comparative advantage, but sourcing the remaining intermediates from abroad, will make export production more competitive. This, in turn, increases exports. However, as countries may only perform a subset of production stages, an increase of gross exports may not be enough and it is important to focus on how much value added a country actually adds to gross exports (e.g. Koopman et al., 2012). On that side of the argument, it is argued that the output expansion of increased gross exports will be large enough to also expand domestic value added in exports (Baldwin, 2012). Hence, a lower domestic relative contribution will be associated with higher domestic value added in exports and thus set a country on a path to industrialization. Opponents argue that, while this might hold for developed countries, it might be different for developing ones. Dalle et al. (2013) argue that developing-country exports face low price elasticities and, therefore, may not increase, although the economy becomes more competitive. Hence, countries that have reduced their domestic contribution may face limited growth of value added because exports do not increase. Second, the authors argue that, even if exports increase, the increase in domestic value added from increased exports might still be offset by the reduction of value added due to the replacement of domestic by foreign suppliers.

[2] There are only seven countries (of which 5 are in Asia) that increased their global manufacturing value added share by 1%-point or more. South Korea increased its share by 3%-points (Baldwin, 2013).

Rodrik (2013a) similarly advertises the stimulation of domestic intermediate suppliers and their importance for industrial development. So how can a country increase its value added in exports? Will fine-grained specialization enable a (developing) country to add this small value-added amount to a large amount of exports and through that increase its value added in manufactured exports? Or will a country's value added in exports grow faster if it increases the relative share of domestic value added per unit of gross exports?

In terms of industrial policies, the latter implies that a country should take an active role in replacing foreign intermediate suppliers by domestic ones. China, for example, follows this explicit policy and encourages local suppliers to imitate foreign ones that supply to the domestic market (Baldwin, 2013). It seems to be working in the sense that Chinese upstream suppliers do indeed replace foreign ones (Baldwin and Lopez-Gonzalez, 2015; Kee and Tang, 2016). More generally, Milberg et al. (2014) argue that developing countries that add only little value to their exports ultimately need to increase this domestic content by taking over upstream stages of production.[3] On the other hand, if countries can indeed maximize value added in exports by adding only little value to their exports, the implication is that, at least in the short run, specialization alone can bring value-added gains from production fragmentation. In that case, the focus should be primarily on facilitating production fragmentation. Escaith (2013) argues for such development paths as a particular strong force for small economies. Samoa, an island of about 200,000 inhabitants, attracted Japanese motor vehicle producers that imported components from Japan to be processed and exported to Australia. Today, this plant makes up of about 20% of Samoa's manufacturing value added (Escaith, 2013). Without reducing the domestic content in exports, this would not have been possible. In this paper, these immediate effects are considered. Long-term gains or losses from production fragmentation, such as learning effects or path dependencies, are not considered.[4]

Section V is concerned with the empirical analysis and provides a set of first results. The next section discusses the use, the interpretation and the calculation of domestic value added in exports and of the domestic value added in exports (DVAX) ratio. The more foreign intermediates are used per unit of export production, the smaller is this ratio. This ratio has already been used in Chenerey et al. (1986), but has been famously revived in the recent literature on global production fragmentation (e.g. Hummels et al., 2001; Johnson and Noguera, 2014). Besides this, the next two sections turn to the method to approximate the measures and its validation, and to the construction of the data set and its comparison to existing sources.

[3] Cheng et al. (2015) for example also argue that upstream stages are more technology intensive than downstream stages.

[4] See Taglioni and Winkler (forthcoming) on dynamic effects of GVC participation and Grossman and Helpman (1991), for example, for a growth model in which specialization in the less technology-intensive sector facilitates R&D activities and has positive effects; see Hausmann et al. (2007) or Young (1991) for models in which specialization in the less technology-intensive sector has negative path-dependency effects.

III. Methodology

III.A. Domestic Value Added in exports, its interpretation and its measurement

There are three ways to measure international trade: gross exports, “value added in trade” and “trade in value added”. To illustrate, let us consider an example with three countries A, B and C. A is producing intermediates that are processed in B, and B exports a final good to C. Gross exports are recorded at each border and thus count the value of A’s intermediates twice: once when exported from A to B, and once again as embodied in the final product when exported from B to C. Country B’s gross exports are larger than its domestic value addition to these gross exports. Gross exports do not clearly differentiate between the domestic and the foreign contribution. Before the “second unbundling”, this did not make a difference, as production was largely domestic but today it does. “Value added in trade” corrects for this “double-counting” by measuring the extent of foreign value added in the domestic production. Hence, the final-good export from B to C is only measured in terms of additional value that is added in B. “Trade in value added” measures trade flows not in terms of arm’s length trading partners, but by country of absorption of value added. Hence, also country A exports value added to C, because the final good to which A contributes is ultimately consumed in C (for a general discussion see Stehrer, 2012). [5]

This paper follows the concept of “value added in trade” that has also been used in Hummels et al. (2001) and Koopman et al. (2012). Hence, it measures the domestic value added in direct trade flows or domestic value added in exports ($dvax$). The DVAX ratio ($dvax\_r$) is then defined as domestic value added in exports over gross exports. This is an inverse measure of Hummel et al.’s (2001) measure of “vertical specialization” (see Los et al., 2016). If the DVAX ratio is large, most intermediates are sourced domestically and if it is small, most intermediates are sourced internationally. This DVAX ratio has been interpreted in several ways. On the one hand, it can be interpreted as a proxy for production stages. A higher DVAX ratio is indicative of a more upstream position in value chains (e.g. Baldwin and Lopez-Gonzalez, 2015; Los and Timmer, 2015). In that regard, scholars have hypothesized that an increase of the DVAX ratio can be interpreted as a sign of industrial upgrading (e.g. Kee and Tang, 2016; Milberg et al., 2014). For example, Kee and Tang (2016) argue that an increase can indicate a replacement of foreign by domestic intermediate suppliers, which implies that a country is able to take over these more upstream production stages. On the other hand, as in the vein of Hummels et al. (2001), variations of that measure have been used as a proxy for GVC integration (e.g. Boffa et al., 2016; Kummritz, 2016). In this line of research, a lower DVAX ratio (i.e., a relatively stronger reliance on foreign intermediates) suggests that a country is more involved in GVCs, hypothesized to be beneficial for the domestic economy. Both interpretations make statements about the channel through which it affects the domestic economy. In this paper, a more

[5] The GVC approach introduced in Los et al. (2015) is another alternative to analyze GVCs. The focus is not on trade flows, but on contributions to final-product value chains by country of completion.

direct way of looking at the role of domestic and foreign intermediates is taken. How does the relative use of these translate into domestic value added in exports? A lower DVAX ratio is expected to increase export competitiveness, but the question is whether this also translates into domestic value added.

The traditional method to calculate the DVAX ratio, which is followed in this paper, is based on input-output tables. Input-output tables provide information on sourcing structures and on the domestic and foreign origin of sourced intermediates (see the next section for a technical exposition; and Miller and Blair, 2009 for an introduction). A recent alternative to calculate the DVAX ratio is introduced in Kee and Tang (2016) who base the calculation on firm-level data for China between 2000 and 2007. Their "domestic value added ratio" (DVAR) is conceptually similar to the DVAX ratio used in this paper. Compared to the firm-level approach, input-output methodologies suffer from an aggregation bias because all firms in one industry are considered to be homogenous. Kee and Tang (2016) argue that the DVAX-ratio levels in Kee and Tang (2016) and Koopman et al. (2012) therefore deviate to some extent. However, the results are qualitatively similar and the input-output approach allows for cross-country comparisons. Moreover, to account for the foreign content in domestically supplied intermediates, Kee and Tang (2016) also have to rely on estimations from input-output tables.

The related concept of "trade in value added" is introduced in Johnson and Noguera (2012; 2014) who calculate the "value added in exports absorbed abroad" (VAX) ratio. This measure relates exports of value added to gross exports and thus indicates the share of domestic value added in exports that is ultimately absorbed abroad to gross exports. This is of interest when analyzing final demand shocks for example (Johnson, 2014), while the "value added in trade" concept is of more interest to evaluate (trade) policies (Lemmers, 2015). Since "trade in value added" assigns value added to final-demand countries, the calculation does exclude returning value added. This is value added that is exported but ultimately absorbed by domestic final demand. The difference between the DVAX ratio and the VAX ratio at the national level is thus the share of returning value added. This difference is typically relatively small for developing countries (between 0.001 and 0.01), but it is large for the United States (0.11) for example (see table 3 in Koopman et al., 2014). Hence, despite the conceptual difference, the results and trends are comparable and will be shown when comparing the data series.[6]

[6] Koopman et al. (2014) and Los et al. (2016) provide a complete decomposition of gross exports encompassing the mentioned concepts.

III.B. Technical exposition

The calculation of the DVAX ratio is based on national input-output tables of which figure 1 shows a simplified version (adapted from Miller and Blair, 2009).[7]

Figure 1. Stylized Input-Output table

	$\mathbf{D_{Agr}}$	$\mathbf{D_{Mfg}}$	$\mathbf{D_{Serv}}$	**FD**	**EXP**	**GO**
$\mathbf{D_{Agr}}$						
$\mathbf{D_{Mfg}}$		$\mathbf{Z_{dom}}$		$\mathbf{fd_{dom}}$	$\mathbf{e}$	$\mathbf{x}$
$\mathbf{D_{Serv}}$						
$\mathbf{M_{Agr}}$						
$\mathbf{M_{Mfg}}$		$\mathbf{Z_{imp}}$		$\mathbf{fd_{imp}}$	$\mathbf{e_{imp}}$	$\mathbf{m}$
$\mathbf{M_{Serv}}$						
VA		$\mathbf{va}$				
GO		$\mathbf{x'}$				

Notes: Agr, Mfg, Serv stands for Agriculture, Manufacturing, Services respectively; FD for final demand; EXP for exports; GO for gross output; D for domestic, M for imported, VA for value added.

$\mathbf{x}$ is an $nx1$ vector of gross output, $\mathbf{m}$ is an $nx1$ vector of total imports, $\mathbf{fd_{dom}}$ is an $nx1$ vector of domestic final demand for final domestic products, $\mathbf{fd_{imp}}$ is an $nx1$ vector of domestic final demand for imported final products, $\mathbf{e}$ is an $nx1$ vector of gross exports, $\mathbf{e_{imp}}$ is an $nx1$ vector of re-exports, $\mathbf{va}$ is an $1xn$ vector of value added, $\mathbf{Z_{dom}}$ is an nxn matrix of direct domestic input requirements, $\mathbf{Z_{imp}}$ is an nxn matrix of direct input requirement of imported goods, and n is the number of industries, which is three in this example. Direct input requirements can be transformed into direct input coefficients by calculating

$$\mathbf{A_{dom}} = \mathbf{Z_{dom}}(\hat{\mathbf{x}})^{(-1)}. \tag{1}$$

Similarly, this can be done for $\mathbf{A_{imp}}$. $\mathbf{A_{dom}}$ is thus an nxn matrix of direct domestic input coefficients and $\mathbf{A_{imp}}$ an nxn matrix of direct foreign input coefficients. This framework is represented by three equations.

$$\mathbf{x} = \mathbf{A_{dom}x} + \mathbf{fd_{dom}} + \mathbf{e} \tag{2}$$

$$\mathbf{m} = \mathbf{A_{imp}x} + \mathbf{fd_{imp}} + \mathbf{e_{imp}} \tag{3}$$

$$\mathbf{x'} = \mathbf{x'A_{tot}} + \mathbf{va} \tag{4}$$

where $\mathbf{A_{tot}} = \mathbf{A_{dom}} + \mathbf{A_{imp}}$ and $\mathbf{A_{tot}}$ are total direct input coefficients. Equation (2) describes that total domestic output of each industry must either be sold to domestic intermediate use, to domestic demand for final products or to exports (which include intermediates and final products). Equation (3) specifies the same relationship for imports. All imported goods must either go to domestic

[7] The following exposition obeys to standard matrix notation. Bold capital letters represent matrices, bold small letters vectors, and small letters in italics integers.

intermediate use, to domestic final demand or must be directly re-exported. Equation (4) specifies that all output must be equal to the sum of the costs for domestic and imported intermediates and of value added. This framework is the basis of the calculation of the DVAX ratio at the country and industry level. The former will be *dvax_r* and the latter $dvax\_r_i$ where i indicates the industry.

Solving equation (2) for **x** gives the well-known Leontief inverse $(\mathbf{I}-\mathbf{A_{dom}})^{(-1)}$,

$$\mathbf{x} = (\mathbf{I}-\mathbf{A_{dom}})^{(-1)}(\mathbf{fd_{dom}}+\mathbf{e}). \quad \textbf{(5)}$$

Equation (5) tells us how much output of each industry is needed in order to produce a given vector of domestic final demand and exports. The production of a final good needs a certain amount of intermediates that are embodied in the final product. These intermediates themselves are also produced making use of intermediates. Hence, in order to trace the full range of intermediates embodied in the production of a final good, it is necessary to trace all prior production steps. This is depicted in the Leontief inverse.

If it is known how much value added is generated in each industry per unit of output, this relationship can be used to calculate how much value added by industry is embodied in the production of a given vector of domestic final demand or exports. This is done by pre-multiplying equation (5) by a vector **v** of value added over gross output ratios by industry, $\hat{\mathbf{v}} = \widehat{\mathbf{va}}\,(\hat{\mathbf{x}})^{(-1)}$. If post-multiplied by the export vector **e**, this gives domestic value added in exports (DVAX).

$$dvax = \mathbf{v}(\mathbf{I}-\mathbf{A_{dom}})^{(-1)}\mathbf{e} \quad \textbf{(6)}$$

To calculate the DVAX ratio, divide $dvax$ by the sum of gross exports, e_{tot},

$$dvax\_r = \frac{dvax}{e_{tot}}. \quad \textbf{(7)}$$

To calculate the DVAX ratio at the industry level of industry *i*, replace the export vector **e** by a vector only depicting exports of industry i, e_i, in the i-th row of the vector.

$$dvax_i = \mathbf{v}(\mathbf{I}-\mathbf{A_{dom}})^{(-1)}\begin{pmatrix} e_i \\ 0 \\ 0 \end{pmatrix} \quad \textbf{(8)}$$

Similarly, divide $dvax_i$ by gross exports e_i.[8]

$$dvax\_r_i = \frac{dvax_i}{e_i} \quad \textbf{(9)}$$

Equation (7) and equation (9) are used to calculate the DVAX ratio at the country and industry level.

[8] Equation (8) and (9) are mathematically equivalent to: $dvax\_r_i = \mathbf{v}(\mathbf{I}-\mathbf{A_{dom}})^{(-1)}\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$. To infer value added in exports of industry *i* ($dvax_i$), equation (8) has to be used.

One assumption underlying this calculation is that all goods are produced making use of the same production technology. Hence, final goods for the domestic market and final goods that are exported, as well as intermediates used domestically and abroad are produced making use of the same production technology. Koopman et al. (2012) point out that this may bias the results in countries that are extensively making use of export-processing zones, such as China, Mexico or Vietnam. The authors show that exports produced in export-processing zones have a much lower DVAX ratio, because firms in export-processing zones are much more exposed to foreign intermediates than other firms. The measures obtained here do not allow for a distinction between different production schemes.

This is related to an aggregation bias. Although equation (7) depicts a measure at the aggregate level, it is important to use disaggregated information when calculating it. Hummels et al. (2001) point this out for their inverse measure of "vertical specialization", but this is analogously the case. Suppose two sub-industries are aggregated into one industry (be it export-processing versus ordinary exporters, or Textiles versus Electronics), but sub-industry (a) exports and (b) does not. Also, (a) has a relatively high ratio of value added over gross output, but (b) a relatively low one. Using information at the disaggregated level to calculate the DVAX ratio, industry (a) exports are weighted by the high industry (a) value added ratio, and zero exports of (b) would be weighted by the low value added ratio. Aggregation leads to weighting all exports of (a) (there are no exports in (b)) with a value added ratio somewhere between that of (a) and (b) (due to aggregation) and thus to a downward bias of actual domestic value added. Hence, if there is a positive correlation between exports and value added ratios, calculations based on aggregate data will be downward biased, and vice versa. The paper at hand uses a relatively detailed industry breakdown of the manufacturing sector of 14 industries and 5 broad sectors. Johnson and Noguera (2014) who also consider long-term trends use one broad sector for all manufacturing industries and four broad sectors in total.

The next section discusses the methodology to implement the calculation of the DVAX ratio without published input-output tables.

III.C. Approximation methodology

Many statistical offices do not publish input-output tables and hence, in principle, prohibit the estimation of "value added in trade" and the calculation of the DVAX ratio. This is especially the case for developing countries, preventing the study of development issues with respect to global value chains. But also in developed countries, input-output tables are not published regularly and older publications are not routinely updated, as is done with other national account data when classification systems are revised. Therefore, alternative estimations are needed to provide cross-country and time-series comparisons. There are two initiatives that aim at covering a large set of developing countries:

the EORA database (Lenzen et al., 2013) and the GTAP database (Aguir et al., 2016). The latter is also applied to create the World Bank's Exports of Value Added Database (EVAD; Francois et al., 2014).[9] The data constructed in this paper differs from these initiatives in several respects.

GTAP does not follow one given methodology to construct national input-output tables, but has defined guidelines for researchers to add national tables individually. This has led to an increasing number of covered countries and sectoral detail over the years. The latest tables for 2011 cover 140 regions and 57 sectors; earlier cross-sections are available about every three years since 1990 (with 66 countries in 1997, and 15 in 1990). However, the focus is on constructing consistent cross-sections rather than time-series, which makes longitudinal analyses difficult (Narayan et al., 2015). For most (and especially developing) countries, the underlying input-output tables do not change over the years and tables are updated by applying new trade data to available tables, i.e., with constant input-output coefficients and gross-output-to-value-added (GO-VA) ratios (Narayan et al., 2015). The GTAP data is applied in EVAD and harmonized to 26 sectors (of which 14 are manufacturing sectors) of up to 118 countries for 2004, 2007 and 2011 and also for 1997 and 2001 for a subset of countries (66 and 87). EORA, on the other hand, covers 187 countries with 26 sectors in multi-region input-output tables between 1990 and 2012. For countries for which tables could be collected, it is also followed an updating strategy by extrapolation. For the remaining countries, EORA is based on a combined proxy table of the United States, Japan and Australia.

The aim of this paper's dataset is to capture long-term developments including most of the developing world. Currently, it covers 93 countries with 19 sectors of which 14 are manufacturing industries between 1970 and 2008. For most countries, only one or very few input-output tables are available and these are for the most recent time periods. Updating tables by extrapolation is likely to work well for developed countries for which the input-output coefficients (and GO-VA ratios) do not vary much over time (e.g., Dietzenbacher and Hoen, 2006). For developing countries, however, backdating a table from 2000 to 1970 is likely to be inferior to constructing proxy tables of several (similar) countries (e.g., Jiang et al., 2012). Therefore, it is not attempted to collect as many national tables as possible and backdate these. Instead, efforts are taken to combine all available data sources on trade flows (split by intermediate use, final consumption and investment), sectoral value added, sectoral gross output, and national account data. These data sources are complemented by constructed proxy tables of input-output coefficients. As input-output tables will not be available for most developing countries for the past and also not necessarily for the near future, it is attempted to develop a methodology that circumvents the need of these to estimate value added in exports.

This is in contrast to the construction of the EORA database that does not fully exploit available data sources, but collects a large amount of input-output tables. In EORA, value added and gross output by

[9] The OECD-TiVA database (OECD, 2015) and the World Input-Output Database (WIOD; Timmer et al., 2015) are not considered here, as they are mainly centered on developed countries and/or recent time periods.

industry is obtained for broad sectors (from UN, 2015a and UN, 2015b) but not for detailed manufacturing industries. Furthermore, also when national account data is available, GO-VA ratios are not always represented in the constructed data. Also, imports are not split into intermediates and final goods based on standard classifications (BEC), but based on the proxy table (see Lenzen et al., 2013). Both discrepancies are visible in the data (see e.g. EORA's Moroccan input-output table 2005 and national account data obtained from UN, 2015a, and trade data obtained from Feenstra et al., 2005). EORA was initially constructed for environmental analyses, such as the study of emissions embodied in domestic final demand. For environmental purposes, the GO-VA ratios are of less importance, but they are for the estimation of domestic value added in exports. Similarly, the amount of imported intermediates is important.

The approximation in this paper is based on the following steps. With equation (1), equations (6) and (8) can be transformed into

$$dvax = \mathbf{v}\left(\mathbf{I} - \mathbf{Z_{dom}}(\hat{\mathbf{x}})^{(-1)}\right)^{(-1)}\mathbf{e}, \quad \textbf{(10)}$$

$$dvax_i = \mathbf{v}\left(\mathbf{I} - \mathbf{Z_{dom}}(\hat{\mathbf{x}})^{(-1)}\right)^{(-1)}\begin{pmatrix} e_i \\ 0 \\ 0 \end{pmatrix}. \quad \textbf{(11)}$$

If a country does not publish input-output tables, $\mathbf{Z_{dom}}$ is unknown. However, the remaining vectors are available from data sources (described below). This section focuses on the estimation of $\mathbf{Z_{dom}}$, which will be approximated by $\mathbf{Z_{dom}^{\mathit{est}}}$. This is done by estimating $\mathbf{Z_{tot}^{\mathit{est}}}$ and $\mathbf{Z_{imp}^{\mathit{est}}}$, as $\mathbf{Z_{tot}^{\mathit{est}}} = \mathbf{Z_{dom}^{\mathit{est}}}+\mathbf{Z_{imp}^{\mathit{est}}}$.

To estimate $\mathbf{Z_{tot}^{\mathit{est}}}$, it is made use of equation (4) that states that all output is made up of intermediates and value added. Subtracting **va** from **x'** provides $\mathbf{ii_{tot}^{u}}$, a *1xn* row vector of total intermediates by using industry. To fill $\mathbf{Z_{tot}^{\mathit{est}}}$, these intermediates by using industry need to be distributed across supplying industries. This is done by assuming a given distribution across supplying industries per unit of intermediate use by using industry. This distribution is approximated by a column-distribution matrix $\mathbf{C_{tot}^{\mathit{proxy}}}$ obtained from a proxy coefficient table. $\mathbf{C_{tot}^{\mathit{proxy}}}$ is thus an nxn matrix of column distributions per unit of intermediate use across supplying industries by using industries, i.e., each column sums to 1. However, the extent (or the share per unit of output) to which a using industry relies on intermediates is retrieved from the data (recall that $\mathbf{ii_{tot}^{u}}$, **x** and **va** are available). $\mathbf{Z_{tot}^{\mathit{est}}}$ is then obtained by

$$\mathbf{Z_{tot}^{\mathit{est}}} = \mathbf{C_{tot}^{\mathit{proxy}}}\,\widehat{\mathbf{ii_{tot}^{u}}}. \quad \textbf{(12)}$$

$\mathbf{Z_{imp}^{\mathit{est}}}$ is obtained by making use of the sums of imported intermediates by supplying industries, $\mathbf{ii_{imp}^{s}}$, and of the sums of imported intermediates by using industries, $\mathbf{ii_{imp}^{u}}$. $\mathbf{ii_{imp}^{s}}$ is thus an *nx1* column vector and $\mathbf{ii_{imp}^{u}}$ a *1xn* row vector. $\mathbf{ii_{imp}^{s}}$ is available from trade data, but $\mathbf{ii_{imp}^{u}}$ must be approximated.

Different industries tend to be differently penetrated by imported intermediates, but across countries, the same industries appear to be relatively more and less penetrated. For example, the Electronics industry is one of the most geographically fragmented industries (i.e., it sources a lot of intermediates from abroad), while Food and Beverages tends to source fewer intermediates from abroad. First, a proxy vector **f** is constructed that depicts average shares of foreign-sourced intermediates in total-sourced intermediates by industry (across a given set of countries). Second, this vector is multiplied by each using industry's extent of used total intermediates ($\mathbf{ii^{u}_{tot}}$) and subsequently the row distribution ($\mathbf{e}$) is calculated. Third, this row distribution is multiplied by the total amount of imported intermediates ($\mathbf{ii^{sum}_{imp}}$). The **f** vector is first multiplied by $\mathbf{ii^{u}_{tot}}$ to adjust for country-specific total intermediate use across industries. The obtained row distribution is then multiplied by the sum of imported intermediates to adjust for the level of intermediate imports. $\mathbf{ii^{u}_{imp}}$ is thus obtained by

$$\hat{\mathbf{d}} = \hat{\mathbf{f}}\,\widehat{\mathbf{ii^{u}_{tot}}}, \qquad \textbf{(13)}$$

$$\hat{\mathbf{e}} = \hat{\mathbf{d}}\left(\widehat{\mathbf{ii^{sum}_{tot}}}\right)^{(-1)}, \qquad \textbf{(14)}$$

$$\widehat{\mathbf{ii^{u}_{imp}}} = \hat{\mathbf{e}}\,\widehat{\mathbf{ii^{sum}_{imp}}}, \qquad \textbf{(15)}$$

where $\mathbf{ii^{sum}_{imp}} = ii^{total}_{imp}\mathbf{u}$ with $\mathbf{u}$ being a *1xn* vector of ones and ii^{total}_{imp} the sum of intermediate imports, and similarly for $\mathbf{ii^{sum}_{tot}}$. Both vectors $\mathbf{ii^{s}_{imp}}$ and $\mathbf{ii^{u}_{imp}}$ serve as row and column constraints in a RAS-procedure to estimate $\mathbf{Z^{\mathit{est}}_{imp}}$, following the GRAS-method introduced in Lenzen et al. (2007). RAS-ing is an iterative process that aims at estimating a new matrix that is constrained by row and column sums, such that it is as close as possible to a given initial matrix. Hence, $\mathbf{Z^{\mathit{est}}_{imp}}$ fully obeys to the obtained data on trade flows (the row and column constraints). The initial matrix in this estimation is a row distribution matrix $\mathbf{R^{\mathit{proxy}}_{tot}}$ that is also based on a proxy coefficient table (an average from a given set of countries). $\mathbf{R^{\mathit{proxy}}_{tot}}$ is thus an *nxn* matrix whose rows sum to 1. Having obtained $\mathbf{Z^{\mathit{est}}_{imp}}$ and $\mathbf{Z^{\mathit{est}}_{tot}}$, $\mathbf{Z^{\mathit{est}}_{dom}}$ can be obtained.

Hence, the methodology hinges on the validity of the proxy coefficient table and of the vector **f**. It is argued that the distribution of sourced intermediates by using industry can be approximated. Hence, it is possible to find sets of countries for which a given industry, say Electronics, sources a similar share from each supplying industry. Second, it is argued that there are more and less foreign-penetrated industries. Taking into account the level of imported intermediates and the relative use of total intermediates within countries, this provides a feasible proxy to distribute imported intermediates across using industries. The next section validates this method in a controlled setting. It uses the World Input-Output Database (Timmer et al., 2015) to construct measures based on the database and based on the described methodology, making use of a subset of information in WIOD.

III.D. Method validation

This section compares the DVAX ratios obtained by making use of $\mathbf{Z}_{\mathbf{dom}}^{est}$ and the DVAX ratio calculated with $\mathbf{Z}_{\mathbf{dom}}$ for the set of countries that is included in the WIOD (Timmer et al., 2015). This comparison validates the two assumptions of the approximation. Hence, the DVAX ratios in this section are entirely based on WIOD data. We refer to "real" vectors and ratios when referring to data based on all information in WIOD, and to "approximated" when referring to ratios constructed with WIOD data, but using only a subset of information and the described methodology.

When using country-specific information (i.e., the "real" matrices and vectors $\mathbf{R}_{\mathbf{tot}}^{proxy}$, $\mathbf{C}_{\mathbf{tot}}^{proxy}$ and $\mathbf{f}$), the DVAX ratios are almost perfectly approximated. Regressing the "real" on the approximated ratios at the aggregate level in levels and in changes, and at the industry level in levels and in changes yields coefficients of 1.00, intercepts of 0.00 and R2 of 1.00 (see appendix table A1). This is an important confirmation that shows that taking the described intermediate steps, such as the GRAS-method, does not alter the outcomes. Hence, this method allows us to combine "real" vectors and matrices (i.e., retrieved from data sources) and approximated vectors and matrices. The more information is used, the closer we get to the "real" values.

Table 1 (a) shows the fit when applying the described method on the 40 WIOD countries, but only calculating one single proxy table as an average across all WIOD countries in the year 1995, underlying the row and column distributions $\mathbf{R}_{\mathbf{tot}}^{proxy}$ and $\mathbf{C}_{\mathbf{tot}}^{proxy}$ and, similarly, only one vector $\mathbf{f}$ with shares of foreign-sourced intermediates by using industry (also an average of 1995). Already this one-size-fits-all approach leads to a fairly good approximation. Ideally, the coefficients would take the value 1 with an intercept 0 and an R2 of 1. This is not the case, but the coefficients are close (although statistically different from 1). Further tests have shown that the bias in the coefficient in columns (1) and (2) stems to about two thirds from using approximated $\mathbf{R}_{\mathbf{tot}}^{proxy}$ and $\mathbf{C}_{\mathbf{tot}}^{proxy}$. Using approximated $\mathbf{f}$ affects the coefficient at the aggregate level to a smaller extent. Hence, to improve the estimation at the aggregate level, $\mathbf{R}_{\mathbf{tot}}^{proxy}$ and $\mathbf{C}_{\mathbf{tot}}^{proxy}$ need to be improved. At the industry level, the bias is already fairly small. However, at the industry level, the inclusion of approximated $\mathbf{f}$ is responsible for the bias in the coefficients. The smaller bias at the industry-level than at the aggregate level is reassuring for an analysis at the industry level. Table 1 (b) shows how dividing countries by regions and using different tables for different years reduces the bias at the aggregate level.[10] Especially the coefficient in column (2) is reduced to 1.01. At the industry level, the R2 increases, but the coefficients are 0.01 lower.

To investigate the ranks of the observations within years and over time, the spearman rank correlations between the "real" and the approximated coefficients for each year and for all pooled observations are

[10] The regions are: OECD (FRA, JPN, DEU, USA, CAN, ESP, AUS, NLD, BEL, SWE, AUT, DNK, FIN, KOR, GBR), small states (CYP, MLT, LUX, TWN), Central and Eastern Europe (POL, LVA, EST, CZE, ROU, SVK, BGR, LTU, SVN, HUN), Emerging economies (RUS, BRA, MEX, CHN, IND, IDN) and others (GRC, PRT, IRL, TUR, ITA).

shown in table 2. At the aggregate level, the correlations range from 0.96 to 0.97 for each year and 0.97 across all years when using the one-size-fits-all approach and from 0.97 to 0.99 with regional proxies. At the industry level, the spearman rank correlation is between 0.95 and 0.96 across all years and pooled for the one-size-fits-all approach and between 0.96 and 0.98 with regional proxies.

Table 1. Linear fit: WIOD vs. method

	(a) One-size-fits-all				*(b) Regional proxies*			
	(1) $dvax\_r$	(2) $\Delta dvax\_r$	(3) $dvax\_r_i$	(4) $\Delta dvax\_r_i$	(1) $dvax\_r$	(2) $\Delta dvax\_r$	(3) $dvax\_r_i$	(4) $\Delta dvax\_r_i$
$Pdvax\_r_{(i)}$	1.07***		0.98***		1.05***		0.97***	
	(0.00)		(0.00)		(0.00)		(0.00)	
$\Delta Pdvax\_r_{(i)}$		1.05***		0.98***		1.01***		0.97***
		(0.01)		(0.00)		(0.01)		(0.00)
Constant	-0.06***	-0.00	0.02***	0.00***	-0.04***	-0.00*	0.03***	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
N	680	640	23,800	22,400	680	640	23,800	22,400
R2	0.98	0.94	0.92	0.67	0.98	0.95	0.93	0.72

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. $dvax\_r$ and $dvax\_r_i$ are defined as above; Δ indicates changes; P indicates the proxied measure based on the described method. Regional proxy and One-size-fits-all refers to the used proxy strategies.
Source: WIOD (Timmer et al., 2015) and author's calculation based on described method.

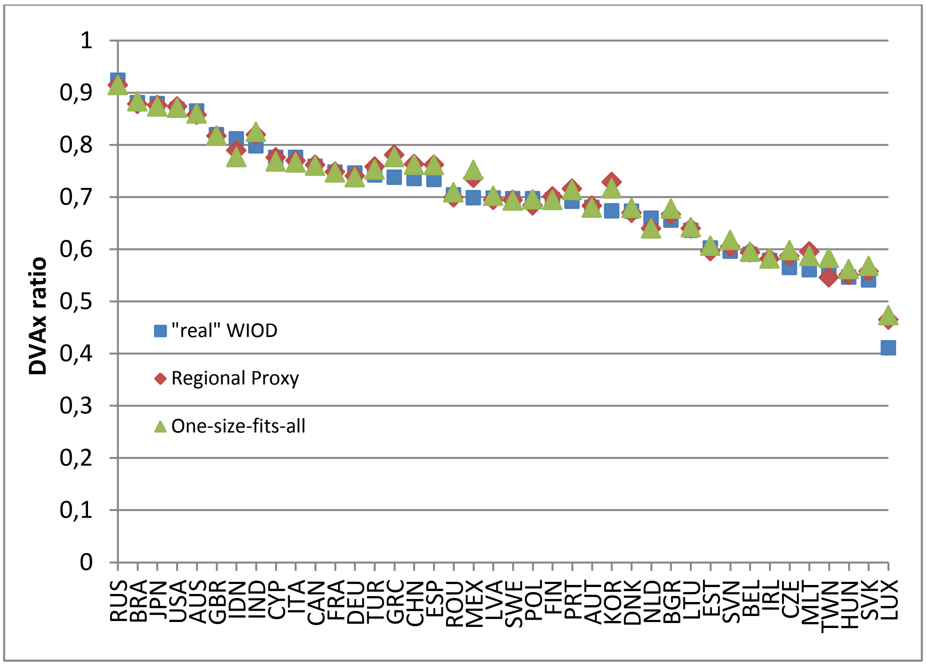
Table 2. Spearman rank correlations: WIOD vs. method

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Regional Proxy Aggregate	0.99	0.99	0.98	0.98	0.98	0.96	0.98	0.97	0.98
Regional Proxy Industry	0.99	0.98	0.98	0.98	0.98	0.96	0.97	0.97	0.97
One-size-fits-all Aggregate	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
One-size-fits-all Industry	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	2004	2005	2006	2007	2008	2009	2010	2011	Pooled
Regional Proxy Aggregate	0.98	0.98	0.98	0.98	0.98	0.99	0.98	0.98	0.99
Regional Proxy Industry	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98
One-size-fits-all Aggregate	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.97
One-size-fits-all Industry	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.96

Note: Regional proxy and One-size-fits-all refers to the used proxy strategies. Aggregate refers to the DVAX ratio at the country level, and Industry to the industry level. The number of observations at the country level is 40 per year, and 680 when pooled; at the industry level, it is 1400 per year and 23,800 when pooled.
Source: WIOD (Timmer et al., 2015) and author's calculation based on described method.

Exemplary for the year 2005, figure 2 shows a scatter plot of data obtained with the approximation methodologies (with regional proxy tables and with one-size-fits-all) and "real" WIOD ratios at the country level. In general, as indicated by table 1 and 2, the approximated ratios match the "real" ones well. Relatively large upward biases are observed for Luxemburg, South Korea and Greece. In some instances, the one-size-fits-all approach does even yield slightly better results that with regional proxies.

Figure 2. Country-level DVAX ratios, 2005



Source: WIOD (Timmer et al., 2015) and author's calculation based on described method

This section shows that the described methodology does indeed a good job in approximating the DVAX ratios. Even with a one-size-fits-all approach, the approximation is not far off. Clearly, to find the "right" DVAX ratios, improvements can be made by finding the "right" matrices and vectors.[11] It was shown that grouping countries will improve the approximation. A split of countries by regions to calculate the proxy column and row distributions improves the estimation at the aggregate level in levels, and especially in differences. At the industry level, the differences tend to be smaller, but approximating the **f** vector is responsible for the deviations. As the differences are small, this methodology proves feasible to construct the DVAX ratio and to estimate value added in exports for a large set of countries throughout time. Given that the underlying data is available, the method can be used to construct a data set that can be piece-wise improved. Starting with the one-size-fits-all approach, additional data can be added to improve the measures in a systematic way. The next section makes use of this methodology and describes the data sources used to construct a data set of value added in exports and DVAX ratios.

[11] Note that this also holds for input-output tables in general. Kee and Tang (2016) discuss how input-output tables are biased, as they rely on surveys that primarily cover large firms. Puzzello (2012) shows how Asian input-output tables were improved by new surveys on sourcing patterns.

IV. Data

IV.A Data sources and data set

The vectors used above organize the following paragraphs.

The gross output vector **x** and the value added vector **va** are retrieved from United Nations Official Country Data (UN OCD; UN, 2015a) and **va** additionally from United Nations National Accounts Estimates of Main Aggregates (UN E; UN, 2015b) for broad sectors in ISIC Rev.3. From the UNIDO INDSTAT3 and INDSTAT4 database (UNIDO, 2006; 2009 and 2015), **x** and **va** are retrieved for disaggregated manufacturing industries. Following the methodologies in Timmer and De Vries (2009), consistent series of the UN OCD and UNIDO data are constructed. For example, this means that the latest available series is used and extrapolated backward by growth rates of other series if there is a break in the series. Second, GO-VA ratios are calculated with UN OCD and UNIDO data. To account for misreporting in the data, the largest and smallest 1% of the ratios in the distribution was deleted and ratios were interpolated instead. This assured that unrealistic values, such as GO-VA ratios below 1 were avoided. Whenever there was an industry for which a country did not have a single value, a world average for each industry-year was calculated and used instead. If ratios were available for only a subset of years of a given industry, the ratios were interpolated between years and kept constant for the beginning and end of the period. The UNIDO data is available in ISIC Rev.2, Rev.3.1 and Rev.4 up to the 4-digit level. Therefore, it had to be aggregated and harmonized with concordance tables obtained from the UN (2015c). UN OCD and UNIDO data were benchmarked by UN E's value added in current US$ by broad sectors. Hence, the UNIDO data's distribution of value added within the manufacturing sector was used to split total manufacturing value added obtained from UN E. Based on this value-added-by-industry series, GO-VA ratios were used to infer gross output by industry (based on UNIDO for manufacturing and based on UN OCD for broad sectors). To complement the Chinese data on gross output by industry and value added by industry, it is additionally made use of the China Industrial Productivity Database Round 3.0 (Wu and Keiko, 2015).

The export vector **e** and the import vector **m** are obtained from recorded trade flows of goods available from UN Comtrade, and compiled in Feenstra et al. (2005). This data is available in SITC Rev.2 from 1963 to 2008. To harmonize, this data was reclassified into ISIC Rev.3.1 making use of concordance tables obtained from the UN (2015c), and following the harmonization strategies applied in Feenstra et al. (2005) in the original construction of the trade data set. The import vector **m** is split into intermediate imports $\mathbf{ii}^{\mathbf{s}}_{\mathbf{imp}}$ and consumption and capital-goods imports $\mathbf{fd}_{\mathbf{imp}}$. This is based on concordances between SITC Rev.2 and BEC (also obtained from the UN, 2015c). Benchmark levels of trade flows are obtained from national account series of gross domestic product (GDP) by expenditure in current US$ obtained from UN OCD (UN, 2015a). Note that the UN Comtrade data does not collect information on services trade. Hence, cross-border transactions of services are not captured. For the calculation of the DVAX ratio, services trade is of interest if it used as intermediate inputs to produce manufactured goods. Not considering these foreign services intermediates is thus expected to lead to an upward bias of the estimated ratio.

Following the methodology in section III.C, value added is deducted from gross output to obtain intermediate use by using industry, which is then distributed across supplying industries. Since value added and output are recorded in basic prices (in nearly all countries in UNIDO), this provides intermediate use in purchaser's prices. This deviates from standard input-output tables that record intermediate use in basic prices to present technical relationships. To account for that, it would be necessary to deduct taxes less subsidies on products from the intermediates in purchaser's prices. Also, trade margins would need to be deducted from intermediate use and be redistributed to the trading sectors. This would require a valuation matrix, which is not constructed in this paper. Hence, the technical relationships deviate in that regard.

In the current version of the data set, the one-size-fits-all approach has been taken. Hence, one average column and row distribution and **f** vector was constructed to proxy for all countries. This proxy is based on an average of all countries included in WIOD in 1995. This will be extended in future versions of the data set with constructed regional proxies that vary over time. Table A2 in the appendix provides a list of countries currently included in the dataset. These are 93 countries with 19 sectors over the period 1970 to 2008, where some of the series start at a later point. Additionally, Bolivia, Venezuela, United Kingdom, Italy, Botswana, Ethiopia, Malawi, Tanzania, Hong Kong and Taiwan are planned for inclusion. The period coverage will also be extended to 2015 and possibly dated back to 1963. The data set covers 19 sectors of which 14 are manufacturing industries. A list and descriptions of the sectoral coverage is provided in table A3.

IV.B. Comparison to existing sources

In this section, the constructed data set is compared to existing sources and studies (WIOD; Johnson and Noguera, 2014) and the case of China is discussed in more detail.

The countries covered in the constructed data and in WIOD are compared in table 3. Table 3 shows the spearman rank correlations between the DVAX ratios based on the one-size-fits-all methodology and the described data sources and the DVAX ratios based on WIOD at the aggregate level and at the industry level. The spearman rank correlations at the aggregate level range between 0.88 and 0.93, and it is 0.91 when all years are pooled. For reference, the pair-wise spearman rank correlations between WIOD, OECD-TiVA (OECD, 2015) and Johnson and Noguera (2014) range between 0.91 and 0.94 (Timmer et al., 2015). The constructed data set is thus in agreement with these alternative data sets. Table 2 showed the rank correlations of the one-size-fits-all approach based entirely on WIOD data. The deviations between these numbers and the ones in table 3 come thus form differences in the data.

On the one hand, the constructed data series (e.g. gross output by industry or trade data) could differ as they come from different sources. These differences tend to be generally small, but deviate for some countries. On the other hand, the constructed data deviates by sectoral detail. In WIOD, 35 industries are modeled, while 19 are included here. The GO-VA ratio of the aggregated industries (mostly services) is not as sensitive to changes over time as when disaggregated. Second, intermediate imports of services are not considered in the constructed data. Services that are embodied in traded intermediate goods are captured, but they are not captured if services cross borders as intermediates. If these cross-border services intermediates make up of a large share of intermediate imports, this may lead to deviations of the DVAX ratio At the industry level, the spearman rank correlation for the pooled data is 0.90 while the reference correlation in table 2 is 0.96. Again, the difference between these two values comes from the used data sources. It is reassuring that the industry-level correlations are in a similar range as the country-level ones.

Table 3. Spearman rank correlation: WIOD vs. constructed data

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Pooled
Aggregate	0.92	0.93	0.90	0.90	0.90	0.90	0.93	0.90	0.88	0.90	0.90	0.88	0.90	0.91	0.91
Industry	0.91	0.92	0.92	0.92	0.90	0.89	0.90	0.89	0.89	0.89	0.88	0.87	0.88	0.86	0.90

Note: The number of observations is 33 per year and 561 pooled at the country level and 602 per year and 10,234 pooled at the industry level.
Source: WIOD (Timmer et al., 2015) and author's calculation based on described method and data sources

To get a sense of the long-term trends, the constructed data is compared to Johnson and Noguera (2014) which is the only study that also considers long-term trends. As mentioned in section III.A, the VAX ratio is conceptually different from the DVAX ratio, but it is reassuring if the general trends coincide. Table 4 shows the start and end year differences in the constructed data and in Johnson and Noguera (2014, table 9). The trends are of similar direction, but deviate for several countries. As noted, one difference is the conceptual difference of returning value added. A second difference is that the end year is 2009 in Johnson and Noguera (2014). This is of importance, as exactly in 2009, international trade slowed down considerably and domestic sourcing increased again. This is visible in data on production fragmentation and depicted in a strong increase of the DVAX ratio. For example, according to WIOD data, Japan's DVAX ratio increased by about 0.05 between 2008 and 2009, explaining large parts of the difference between the two series in table 4. Similar increases can be observed for most countries in the series and are indicated in the last column of table 4. On the other hand, the constructed data series deviate in other respects. The key differences are that Johnson and Noguera (2014) do make use of input-output tables for benchmark years, but aggregate into four broad sectors and, most importantly, do not make use of information on GO-VA ratios other than provided in the input-output tables. For example, the most historical input-output table of Greece is from 1995. This table serves as the benchmark for all previous years to infer GO-VA ratios and thus sector-level intermediate input use. Shifts between subsectors within the manufacturing sector that change the aggregate GO-VA ratio (e.g. between Textiles and Electronics) and GO-VA-ratio changes within subsectors are not depicted. In this paper, GO-VA ratios are retrieved at a disaggregated level to update this information on a yearly basis. The case of Greece shows how the two methodologies yield different results. Updating GO-VA ratios has the advantage that it captures structural changes of the economy, which might be of great importance for countries that do undergo such changes. Besides Greece, also Belgium and Chile show considerable differences, and similarly, for both countries, input-output tables before 1995 and 1996, respectively, are not used. Considering the countries for which historical input-output tables are used (Australia, Canada, Denmark, France, Japan, Netherlands, United States), similar to most other countries, the largest part of the difference between the two series can be explained by the uptick of the DVAX ratio in 2009. However, also after considering the uptick, the start-end-year differences in the constructed series tend to be about 0.03 to 0.04 larger than in Johnson and Noguera (2014). Whether this difference is due to the aggregation in Johnson and Noguera (2014), the use of input-output tables of benchmark years or the conceptual difference, it is reassuring that the main time series properties are coinciding. However, it also shows how the different methodologies can lead to different results. Unfortunately, countries that do undergo structural changes are typically the ones that publish the least (historical) input-output tables (but they would be most useful). Without such historical tables, it is argued here that GO-VA ratios are crucial in depicting the trends.

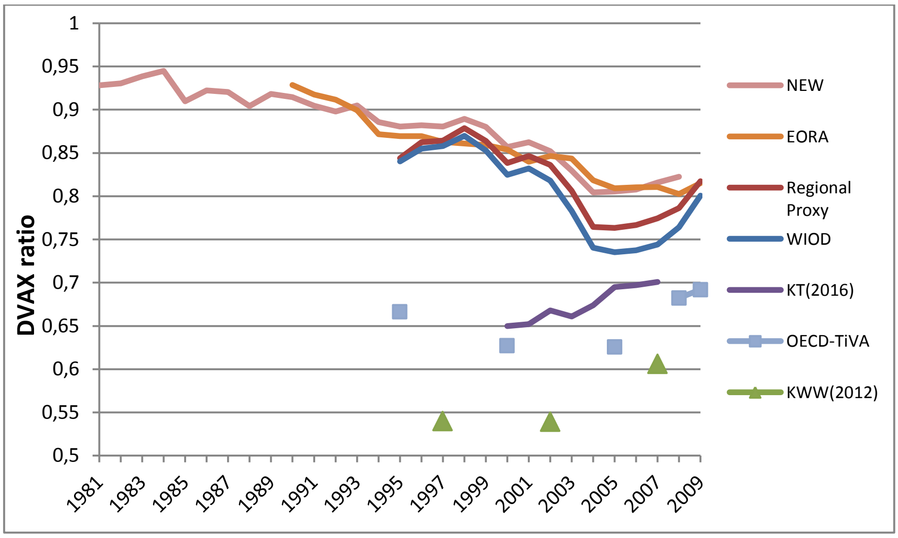
Table 4. DVAX ratios over time: Johnson and Noguera (2014) vs. constructed data

Country	Time period	DVAXr	Time period	JN(2014)	WIOD uptick
Argentina	1970-2008	-0.11	1970-2009	-0.06	-
Australia	1970-2008	-0.12	1970-2009	-0.04	0.04
Austria	1970-2008	-0.19	1970-2009	-0.13	0.04
Belgium	1970-2008	-0.25	1970-2009	-0.10	0.06
Brazil	1970-2008	-0.13	1970-2009	-0.06	0.03
Canada	1970-2008	-0.09	1970-2009	-0.10	0.02
Chile	1970-2008	-0.25	1970-2009	-0.10	-
Czech Republic	1993-2008	-0.14	1993-2009	-0.05	0.04
Denmark	1970-2008	-0.08	1970-2009	-0.01	0.03
Spain	1970-2008	-0.13	1970-2009	-0.13	0.05
Estonia	1992-2008	-0.06	1993-2009	0.04	0.05
Finland	1970-2008	-0.03	1970-2009	-0.06	0.03
France	1970-2008	-0.19	1970-2009	-0.10	0.04
Greece	1970-2008	-0.32	1970-2009	-0.07	0.06
Hungary	1970-2008	-0.32	1970-2009	-0.23	0.05
India	1970-2008	-0.23	1970-2009	-0.17	-0.01
Ireland	1970-2008	-0.13	1970-2009	-0.19	-0.01
Israel	1970-2008	-0.14	1970-2009	-0.04	-
Japan	1970-2008	-0.11	1970-2009	-0.03	0.05
Republic of Korea	1970-2008	-0.16	1970-2009	-0.15	0.04
Mexico	1970-2008	-0.20	1970-2009	-0.21	0.00
Netherlands	1970-2008	-0.15	1970-2009	-0.08	0.03
Norway	1970-2008	-0.03	1970-2009	0.08	-
New Zealand	1970-2008	-0.08	1970-2009	0.01	-
Poland	1970-2008	-0.13	1970-2009	-0.09	0.04
Portugal	1970-2008	-0.15	1970-2009	-0.09	0.06
Romania	1970-2008	-0.26	1970-2009	-0.22	0.04
Slovakia	1993-2008	-0.15	1993-2009	-0.11	0.05
Slovenia	1992-2008	-0.14	1993-2009	-0.05	0.05
Sweden	1970-2008	-0.15	1970-2009	-0.10	0.03
Thailand	1970-2008	-0.25	1970-2009	-0.21	-
USA	1970-2008	-0.15	1970-2009	-0.09	0.04
South Africa	1970-2008	-0.15	1970-2009	-0.06	-

Note: – indicates that the country is not included in WIOD.
Sources: described data set, JN(2014) is Johnson and Noguera (2014, table 9) and WIOD (Timmer et al., 2015).

As the discussion on the measurement of the DVAX ratios has recently been centered on the case of China, this is discussed in more detail. China is one of the few countries that could defy the global trend of ever decreasing DVAX ratios and China's DVAX ratio was increasing again according to the most recent estimations (most notably, Kee and Tang, 2016 and Koopman et al., 2012). However, this trend is captured differently across studies. The key issue is the explicit treatment of export-processing zones. Exporters in these zones make much more use of foreign intermediates and they also export relatively more. Therefore, aggregation leads to an error (see section III.B). Figure 3 graphs the DVAX ratio of China between 1980 and 2009 of the major studies and databases. Additionally, it includes China's ratio based on the approximation method with regional proxy tables (Regional proxy) and the constructed data for China (NEW).

Figure 3. China's DVAX ratio



Sources: NEW is the data constructed in this paper; EORA the Eora database (Lenzen et al., 2013); Regional Proxy as described above; WIOD is data from WIOD (Timmer et al., 2015); KT(2016) is Kee and Tang (2016); OECD-TiVA is the OECD database (OECD, 2015) and KWW(2012) is Koopman et al. (2012).

Studies that explicitly treat processing exporters find a larger increase of the DVAX ratio than other studies. Koopman et al. (2012) use China's input-output tables of 1997, 2002 and 2007 and model the export-processing sector separately. The authors find a substantially higher DVAX ratio in 2007 than in 2002. This is also shown in Kee and Tang's (2016) calculation based on firm-level data, showing an increase between 2000 and 2007. For non-processing exporters, the authors show in fact a downward trend and hence, this increase is entirely due to processing exporters. According to Kee and Tang (2016), the difference to Koopman et al. (2012) is due to an overrepresentation of large firms in input-output tables. Large firms tend to use more foreign intermediates and therefore downward bias the DVAX ratio. The latest version of the OECD-TiVA (OECD, 2015) database does also explicitly model the export-processing sector using the same input-output tables as Koopman et al. (2012). The data show a higher DVAX ratio in 2008 compared to 2005. However, this upward trend can also be picked up if the export-processing sector is not modeled. The DVAX ratio level of these studies is generally higher, because of the aggregation of processing and ordinary exporters (and because processing exports tend to export more and make more use of foreign intermediates). In the WIOD data, the upward trend starts in 2005, which is comparable to OECD-TiVA's start of the increase. The WIOD data is also based on China's input-output tables of 1997, 2002 and 2007. Reassuringly, this upward trend, although with smaller magnitude, is also shown in the constructed data of this paper (and with WIOD data and regional proxies). The magnitude in WIOD is 0.03 between 2005 and 2008, and 0.02 in the constructed data, where the upward trend starts in 2004. It seems that this trend can be picked up, because changing input-output coefficients are not the main driving force of the DVAX ratio. It reacts to the extent of imported intermediates and changing GO-VA ratios indicating how much intermediates are used. This uptick in the Chinese DVAX ratio is not depicted in the EORA data until after 2008 (until 2010). This increase may in fact be driven by the global trade slowdown in that period rather than China-specific factors. As imported intermediates and GO-VA ratios are incorporated less rigorously in the construction of EORA, this is confirmative of their importance. On the other hand, incorporating the 2007 Chinese input-output table does not per se capture the trend (as it is incorporated in EORA).

The goal of this method is to provide approximations of key indicators across countries and time. Therefore, the method limits itself to data that is widely available. It is reassuring that compared to available data sources (WIOD in this case), the cross-country and time-series spearman rank correlations are relatively high. Compared to Johnson and Noguera (2014), the major long-term trends are also depicted in the data. Even though export-processing firms are not explicitly considered and even though no Chinese input-output tables have been used, the current upward trend is depicted. In comparison to EORA, it shows that there may be more value in obeying to trade data and GO-VA ratios than in using a particular input-output table.

V. Quantitative analysis and results

Equipped with the data set described in the previous section, it is possible to study long-term trends of domestic value added in exports. The analysis centers on the question whether the relative contribution to a country's exports (DVAX ratio) is correlated with growth of the domestic value-added content in exports (DVAX). On the one hand, a replacement of domestic upstream suppliers by foreign ones (a decrease of the DVAX ratio) is expected to increase export competitiveness, which, in turn, should be associated with an increase of gross exports. If this output expansion is large enough, it will compensate for the replacement of domestic upstream suppliers and also increase domestic value added in exports (DVAX). However, this output expansion may not fully compensate for the replacement of domestic upstream suppliers and thus be associated with a smaller increase of value added.

V.A. Estimation strategy

In the spirit of Cowen (2016), the interest is in value added that is generated in the production of exports. A possible specification would estimate the effect of an increase of the relative domestic contribution in gross exports on value added in exports growth. This would indicate whether an actual change in the domestic contribution is associated with a change in value added in exports.

$$\Delta\ln(dvax)_{jt} = \alpha_0 + \beta\Delta\ln(dvax\_r)_{jt} + \varepsilon_{jt}, \quad (16)$$

where, as above, *dvax* is domestic value added in exports and *dvax_r* the ratio of domestic value added to gross exports, j is country, t the time period, Δ indicates differences and ε_{jt} is the error term. A positive coefficient of β would indicate that increasing the domestic content in exports is associated with higher growth of value added in exports. However, this specification is subject to built-in endogeneity, because *dvax_r* is a function of *dvax* and of gross exports (*gx*). *gx* is the sum of *dvax* and foreign value added in exports (*fvax*). Hence, β is positive if *dvax* is growing faster in countries in which *dvax* is growing faster than *fvax*. Note that β is not positive by construction. It is also possible that *dvax* is growing faster in countries in which *fvax* is growing faster than *dvax*. The correlations in the data set suggest that, at the country as well as at the industry level, value added in export growth is larger in countries in which *dvax* growth outpaces *fvax* growth. While this correlation indicates that there could be a positive impact of taking over a relatively larger range of production stages, we cannot make inferences based on these correlations and estimates. To estimate this specification, it would be necessary to find an appropriate instrument that captures whether a country increases or decreases its relative domestic contribution.[12]

Instead, the specifications in equation (17) at the country and (18) at the industry level are estimated.

$$\Delta\ln(dvax)_{jt} = \alpha_0 + \beta\ln(dvax\_r)_{jt-k} + \gamma\mathbf{c} + \eta_j + \upsilon_t + \varepsilon_{jt}\ , \quad (17)$$

$$\Delta\ln(dvax)_{ijt} = \alpha_0 + \beta\ln(dvax\_r)_{ijt-k} + \gamma\mathbf{c} + \eta_{ji} + \varphi_{jt} + \upsilon_{it} + \varepsilon_{ijt}\ , \quad (18)$$

where $\ln(dvax\_r)_{jt-k}$ and $\ln(dvax\_r)_{ijt-k}$ are the lagged levels of the DVAX ratios, **c** is a vector of control variables, η_j are country fixed effects, υ_t are year fixed effects, η_{ji} are country-industry fixed effects, φ_{jt} are country-year fixed effects, υ_{it} are industry-year fixed effects, *i* is industry and ε_{jt} and ε_{ijt} the error terms.[13] The use of lagged DVAX ratios is intended to reduce the problem of endogeneity. Future growth of value added in exports does not affect the lagged relative domestic contribution to exports. Similarly, the sets of fixed effects reduce potential unobserved heterogeneity to country-industry-time-varying variables. Boffa et al. (2016) estimate a comparable regression

[12] Kummritz (2016) constructs an instrument variable for the level of GVC integration based on trade costs. It has to be evaluated whether similar instruments may provide useful to indicate changes.

[13] The control variables include GDP and GDP per capita and are obtained from PWT8.1 (Feenstra et al., 2015). Output-based country-level price indices from PWT8.1 are used for deflation.

model by regressing GDP per capita on the lagged amount of foreign value added in exports. The idea in such estimations is that the sum of imported intermediates used in export production has positive effects on the economy through spillover effects, for example. Here, the channel is from the relative use of foreign intermediates to export competitiveness, exports and value added in exports. Equation (17) and (18) tell us whether countries (or country-industries) that have a relatively higher domestic contribution tend to experience faster growth of value added in exports. The results below are presented as first correlations that guide our thinking, while more work on the econometric specification is needed.

As the analysis is framed by the question how countries can indsutrialize, value added in manufactured exports is considered. Agriculture, mining, electricity, construction, transport and services exports are set to zero. However, the analysis of manufactured exports does take into account all non-manufactured upstream intermediate inputs, as all backward linkages of the manufacturing industry are included (see the use of the Leontief inverse in section III).

The results presented in the following tables are based on a restricted sample excluding the 1% most extreme values of the main left-hand side variable. The results are of similar sign and statistical significance, but larger in magnitude when running it on the full sample. The restricted sample assures that the effects are not driven by few observations. Table 5 summarizes the distributions of the main variables at the country and industry level.

Table 5. Summary of variables

Variable	Mean	S. D.	10%	25%	Median	75%	90%	N
$\Delta\ln(dvax)$	0.049	0.153	-0.115	-0.022	0.047	0.123	0.219	2,902
dvax_r	0.709	0.137	0.530	0.635	0.721	0.807	0.876	2,902
$\Delta\ln(dvax)_i$	0.063	0.280	-0.265	-0.079	0.053	0.194	0.412	33,033
$dvax\_r_i$	0.699	0.150	0.493	0.612	0.720	0.810	0.876	33,033

Note: variables as defined above. % are percentiles, S.D. is standard deviation, N is number of observations.
Source: described data set and author's calculation.

V.B. Results

Table 6 shows the regressions at the country level and table 7 at the industry level. Column (1) of both tables shows the unconditional correlations of the lagged DVAX ratio and subsequent growth of value added in exports. In both cases, the coefficient is negative, indicating that countries and industries with a lower initial DVAX ratio tend to experience faster growth of value added in exports. This coefficient is not statistically significant at the country level. This may be due to the stylized finding in Baldwin and Lopez-Gonzalez (2015) that larger countries tend to have higher DVAX ratios and may witness smaller growth rates of value added in exports. Including lagged aggregate GDP to proxy for economic size and lagged GDP per capita to proxy for development stage turns the coefficient statistically significant. This similarly holds when controlling for growth of GDP per capita and lagged levels of value added in exports. This also holds when including different sets of fixed effects.

Table 6. Country-level regressions

VARIABLES	(1) Δln(dvax)	(2) Δln(dvax)	(3) Δln(dvax)	(4) Δln(dvax)	(5) Δln(dvax)	(6) Δln(dvax)
dvax_r	-0.0342	-0.0693***	-0.0443**	-0.0931**	-0.148***	-0.0961**
	(0.0208)	(0.0234)	(0.0214)	(0.0374)	(0.0413)	(0.0420)
N	2,902	2,902	2,902	2,902	2,902	2,902
R2	0.001	0.010	0.065	0.035	0.100	0.132
Controls	NO	YES	NO	NO	NO	YES
Year FE	NO	NO	YES	NO	YES	YES
Country FE	NO	NO	NO	YES	YES	YES

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Variable are defined as above, N is the number of observations. Controls are: lagged GDP, lagged GDP per capita and lagged level of value added in exports.
Source: described data set and author's calculation.

At the industry level, all coefficient are statistically significant and negative. Including different sets of fixed effects increases the coefficient in magnitude. The favored specification includes country-year, country-industry and industry-year fixed effects. Taking this coefficients at face value, a 0.1 lower DVAX ratio is associated with 0.03 percentage point higher growth rate of value added in exports.

Table 7. Industry-level regression

VARIABLES	(1) $\Delta\ln(dvax)_i$	(2) $\Delta\ln(dvax)_i$	(3) $\Delta\ln(dvax)_i$	(4) $\Delta\ln(dvax)_i$
$dvax\_r_i$	-0.0469***	-0.115***	-0.153***	-0.344***
	(0.0103)	(0.0203)	(0.0230)	(0.0542)
N	33,033	33,033	33,033	33,033
R2	0.001	0.030	0.060	0.329
Country FE	NO	YES	NO	NO
Year FE	NO	YES	YES	NO
Industry FE	NO	YES	NO	NO
Country-Year FE	NO	NO	NO	YES
Country-Industry FE	NO	NO	YES	YES
Industry-year FE	NO	NO	NO	YES

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
Variable are defined as above, N is the number of observations.
Source: described data set and author's calculation.

The presented correlations are thus suggestive of a positive effect from reducing the relative contribution to exports. Value added in exports tends to grow faster if the initial domestic contribution is lower. Do these relationships hold throughout time and for all countries and industries? Or is this a phenomenon that primarily works for a set of emerging countries that are specializing in downstream stages of high-technology exports, such as Electronics? Additional work is attempted to disentangle the effects by time periods, sets of countries (e.g. development stage) and industries.

VI. Conclusion

Global value chains have altered the way industrial production is organized across countries. Ignited by Baldwin's (2006) idea that industrialization has become easier but less meaningful, global value chains have caught increasing attention from a development perspective. But how can countries increase their value added in manufactured exports?

Global value chains are still a relatively recent phenomenon in the empirical macroeconomic literature, and the link to economic development is just emerging (e.g. Kummritz, 2016). Data availability of developing countries still remains a crucial bottleneck, as it has to be made sense of data collected by national statistical institutes that are just starting to incorporate the concept of global value chains.

The proposed method and collected data helps to grasp long-term developments of production fragmentation even if national statistical institutes do not provide sufficient data. It allows for a calculation of domestic value added in exports and the DVAX ratio for a wide range of countries and time periods. The presented correlations show that making increasingly use of foreign intermediate suppliers, i.e., reducing the domestic content in exports, is correlated to higher growth rates of value added in exports. This is in line with the idea that making use of foreign intermediates is associated with higher export competitiveness that ultimately translates into higher value added in exports (e.g. Baldwin, 2013; Taglioni and Winkler, forthcoming). The presented correlations do not confirm the recent idea that countries must increase their domestic relative contribution to benefit most in terms of value added in exports (as suggested in Kee and Tang, 2016; Milberg et al., 2014; Rodrik, 2015). Future work aims at capturing whether these gains are universal. This negative correlation between the DVAX ratio and value added in exports growth may be driven by developed countries, which, in turn, would call for different strategies for development. Furthermore, it will need to be disentangled whether this correlation is particularly large in specific industries. Is this correlation mainly happening in low-skill industries and high-technology industries require different strategies? Also, is it really just a recent phenomenon that countries can benefit from production fragmentation or have East Asian countries industrialized in a very similar manner?

Providing answers to such questions will sharpen our understanding of the role of production fragmentation for economic development. Quantitative studies on the topic are emerging and will provide feedback for theoretical models and inform the policy debate.

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Appendix

Table A1. Linear fit: WIOD vs. method based on WIOD

	(1) $dvax\_r$	(2) $\Delta dvax\_r$	(3) $dvax\_r_i$	(4) $\Delta dvax\_r_i$
$Pdvax\_r_{(i)}$	1.00***		1.00***	
	(0.00)	(0.00)		
$\Delta Pdvax\_r_{(i)}$		1.00***		1.00***
		(0.00)	(0.00)	
Constant	-0.00***	0.00	-0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
N	680	640	23,800	22,400
R2	1.00	1.00	1.00	1.00

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. $dvax\_r$ and $dvax\_r_i$ are defined as above; Δ indicates changes; P indicates the proxied measure based on the described method.
Source: WIOD (Timmer et al., 2015) and author's calculation based on described method.

Table A2. List of countries

Latin America & Carribean	**OECD**	**Central Eastern Europe & Central Asia**	**Middle East & North Africa**	**Sub-Saharan Africa**	**East & South Asia**
Argentina	Australia	Azerbaijan	Algeria	Burkina Faso	Bangladesh
Brazil	Austria	Belarus	Egypt	Cameroon	China
Chile	Belgium	Bosnia and Herzegovina	Iraq	Gabon	India
Colombia	Canada	Croatia	Israel	Ghana	Malaysia
Costa Rica	Denmark	Cyprus	Jordan	Kenya	Philippines
Dominican Republic	France	Czech Republic	Kuwait	Mauritius	Republic of Korea
Ecuador	Finland	Estonia	Lebanon	Mozambique	Singapore
El Salvador	Germany	Georgia	Morocco	Nigeria	Sri Lanka
Guatemala	Ireland	Greece	Oman	Senegal	Thailand
Honduras	Japan	Hungary	Qatar	South Africa	
Jamaica	Netherlands	Kirgizstan	Saudi Arabia	Zambia	
Mexico	New Zealand	Latvia	Syrian Arab Republic	Zimbabwe	
Nicaragua	Norway	Lithuania	Tunisia		
Panama	Portugal	Mongolia	Turkey		
Paraquay	Spain	Poland	United Arab Emirates		
Peru	Sweden	Romania	Yemen		
Trinidad and Tobago	United States of America	Russia			
Uruquay		Slovakia			
		Slovenia			
		The former Yugoslav Republic of Macedonia			

Table A3. List of sectors

ISIC Rev.3.1	Description
AtB	Agriculture, Hunting, Forestry and Fishing
C; E	Mining and Quarrying; Electricity, Gas and Water Supply
15t16	Food, Beverages and Tobacco
17t18	Textiles and Textile Products
19	Leather, Leather and Footwear
20	Wood and Products of Wood and Cork
21t22	Pulp, Paper, Paper , Printing and Publishing
23	Coke, Refined Petroleum and Nuclear Fuel
24	Chemicals and Chemical Products
25	Rubber and Plastics
26	Other Non-Metallic Mineral
27t28	Basic Metals and Fabricated Metal
29	Machinery, Nec
30t33	Electrical and Optical Equipment
34t35	Transport Equipment
36t37	Manufacturing, Nec; Recycling
F	Construction
I	Inland, Water, Air Transport; Other Supporting Transport Activities; Post and Telecommunications
Services	Market and Non-Market Services