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Why has China's vertical specialization declined?

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ABSTRACT

Vertical specialization (VS) is quantified by the VS share, which mea-
sures the average import content per dollar of exports. A character-
istic of China's export trade is its strong dependence on assembly
and processing activities. To take proper account of this, China's
VS shares should explicitly distinguish processing export produc-
tion from other production. We estimate China's annual VS shares
from 2000 to 2012—the latest year for which a special input–output
table is available that makes such an explicit distinction. We find that
VS shares increased from 2000 to 2004 and subsequently started to
decrease. To explore why it has declined, we introduce a new struc-
tural decomposition approach. We find that the decrease of the VS
share appears to have been driven mainly by the substitution of
imported intermediates by domestic products. This occurred in par-
ticular in the production of exports, which implies an upgrading of
China's position in global value chains.

1. Introduction

Recent economic globalization is characterized by international fragmentation. This has
led to the rapid growth of trade in components and parts (Yi, 2003). To measure a coun-
try's involvement in international fragmentation, Hummels et al. (2001, hereafter HIY)
proposed the concept of 'vertical specialization' (VS), which is defined as the imports
embodied in one unit of exports. The VS share is an important indicator to measure the
structural interdependence of the world economy (Amador and Cabral, 2009). A larger VS
share implies more in-depth involvement in international fragmentation, that is, a higher
dependence of a country on imported inputs for its export production. From another per-
spective, a higher VS share implies less domestic value added (DVA) is generated by the
exports. The VS share thus reflects how much a country 'earns' on its exports, and its

changes therefore indicate a country's economic development pattern. A large body of literature has found that in past decades the VS share has increased not only for the world's average but also in most of the developed countries. These include the United States, Germany (Hummels et al., 2001), the United Kingdom, Canada, France, Australia (Chen et al., 2005), and South Korea (Chen and Chang, 2006).[1]

China, as one of the most important engines for the recent trade boom, has become a popular object of study for international economists. As a consequence, China's VS share has been thoroughly measured.[2] The literature (e.g. Ping, 2005; Hwang et al., 2011) documents that prior to 2005, China's VS share rose sharply. Ping (2005) showed that it soared from 14% in 1992 to 22% in 2002, an increase that had previously taken most OECD countries about 20 years to achieve. An important reason for this sharp increase was that China's trade became dominated by processing trade, which was triggered by a very biased policy.[3] For example, materials imported into China were exempted from tariffs if they were used for processing trade. This policy led to an increase of imported intermediate inputs in the production of processing exports rather than in other types of production, including the production of ordinary exports (Yang et al., 2015). However, standard input–output (IO) tables do not reflect the appropriate role of processing trade, and surprisingly low levels of VS have thus been reported. Therefore, special IO tables have been constructed that separate processing exports from other exports (Dean et al., 2011; Yang et al., 2015). Using these special tables revealed much higher levels of VS.

After decades of rapid trade growth, the policy regarding processing trade changed in the mid-2000s. In 2006, the Ministry of Commerce designated several commodities groups for which processing trade became prohibited or restricted.[4] Meanwhile, China's minimum-wage policy reform in 2004 has effectively increased China's labor costs.[5] This has caused some multinational enterprises, which use labor costs as an important determinant of their location, to move their processing and assembly operations to countries where labor is cheaper than in China. As a result, the share of processing exports in total exports declined from 55.3% in 2002 to 34.1% in 2016.[6] This decrease in the share of processing

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[1] In contrast, Chen et al. (2005) found that the VS share of Japan and Denmark has declined for the period from 1985 to 1995. In general, there is strong support for the increase in VS in the last decades. Amador and Cabral (2009) observed a strong increase of VS activities in the world's main areas from 1967 to 2005. Using the WIOD data, Johnson (2014) reported that the ratio of DVA to exports decreased from 1995 to 2008 for 18 of the top 20 exporting countries, implying increasing VS shares. Los et al. (2015) found that the share of foreign value added (i.e., from outside the country-of-completion) in almost all final goods has increased since 1995, implying an increase in global fragmentation.

[2] Due to official statistics, China in this paper indicates mainland China only.

[3] Processing trade refers to the business activity of importing all, or part of, the raw and auxiliary materials, parts and components, accessories, and packaging materials from abroad in bond, and re-exporting the finished products after processing or assembly by enterprises within mainland China. Processing trade in this paper includes two types. (1) Processing with Imported Materials (PIM): business enterprises in China make a foreign exchange payment for imported raw and auxiliary materials, parts and components, accessories, and they export the finished products after processing or assembly. (2) Processing & Assembling (P&A): business enterprises do not make a foreign exchange payment for the imports, but just charge the foreign party a processing fee.

[4] In 2015, processing exports were prohibited for 1862 commodities, accounting for 14% of all commodities at ten-digit Harmonized System codes (Announcement No.59 of 2015 of the Ministry of Commerce, PRC. see: http://www.mofcom.gov.cn/article/b/c/201501/20150100863677.shtml). HKTDC (2007) reports that China's processing trade policy changes reduced the processing trade of products with low domestic value-added, high pollution, and high energy and resource consumption.

[5] Minimum wages were first introduced in China in 1993. They really took effect, however, only after 2004 when the minimum-wage coverage was extended to migrant workers and the penalties in case of violation were dramatically increased. Each province, municipality, autonomous region, and even district sets its own minimum wage according to both local conditions and national guidelines (Mayneris et al., 2014).

[6] The data are from the China's National Bureau of Statistics.

exports suggests an overall decline in the VS share.[7] We ask, however, whether or not other causes have also played a role.

This question is important because different answers have different policy implications. If the decline in the share of processing exports is the main driver, the decreasing VS shares suggest that the 'world's factory' is moving out of China. On the other hand, the decreasing VS shares may have been caused by changes in the input structure. The production of exports has become less dependent on imports and relies, instead, more on domestic inputs. In this case, decreasing VS shares suggest that China's role in the global value chains (GVCs) has been upgraded. This would change the perception that China will always reside at the lower end of the global production chain and obtain limited DVA from its exports (Koopman et al., 2012).

This paper first provides annual measurements of China's VS share during the period 2000–2012, based on the special IO tables that distinguish processing trade from other production. Next, we apply a structural decomposition analysis (SDA) to investigate the major drivers of the changes in China's VS share from 2002 to 2012. To this end, a new decomposition is developed. It decomposes the VS share change into 14 components. The new decomposition measures the contribution of the three different production types separately and splits changes in their production technologies into smaller components. It distinguishes substitution: between primary and intermediate inputs; between domestically supplied and imported inputs; and between inputs provided by Domestic Enterprises (DEs) and by Foreign-Invested Enterprises (FIEs). Compared with existing decompositions (Pei et al., 2012), our decomposition provides a much more detailed anatomy of the changes in China's input structure.

We find that since 2005, China's VS share has reversed its upward trend and declined steadily. The decomposition results show that the main driver is changes in the input structure, especially the substitution of imported intermediates by domestically produced intermediates. This implies that China's declining VS share is to a large extent the result of the upgrading of China's production all along the GVCs. However, simultaneous changes in the composition of the export bundle have increased China's VS share from 2002 to 2007. This is surprising because the share of processing exports, which depend more on imports than nonprocessing exports, has declined dramatically in this period. It appears that this is due to the change in the commodity composition of the exports toward capital-intensive products. After the 2008 global financial crisis, changes in the commodity composition of exports have decreased the VS share from 2007 to 2012.

2. Measurement of the VS share

2.1. Overview

The empirical literature suggests a range of different methods to quantify the degree of VS. In summary, the main approaches can be classified into two types: one using international trade statistics, the other employing IO tables. When using international trade

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[7] Koopman et al. (2012) and Yang et al. (2015), report that China's VS share declined from 2002 to 2007, but they fail to explain why this happened. The focus of their work was to propose new VS share measurements based on the IO tables that distinguish the production of processing exports from other production. Using these tables, Chen et al. (2012) documented that the DVA content in China's exports increased for 2002–2007. Kee and Tang (2016) did so for 2000–2007, using *firm- and customs transaction-level data*. This implies that the counterpart of the share of DVA (i.e., the VS share) declined.

statistics, one of the widely accepted methods is to measure the components or materials that are imported (or exported) to be processed and then re-exported (re-imported) again (Helg and Tajoli, 2005; Swenson, 2005). Also purchased goods by multinational enterprises from a foreign affiliate (Lawrence, 1994; Slaughter, 1995) and the measurement of trade in intermediate goods, parts, and components (Yeats, 1998) have been frequently used. The advantage of these methods is that they rely only on international trade statistics, implying high accessibility of the data and comparability across countries. On the other hand, however, these methods do not provide accurate measurements of VS. The first two methods undervalue the degree of VS, as they cannot capture VS activities beyond pure, direct (i.e. without any intermediate steps) processing trade or outsourcing, and the third method relies too heavily on the product classification (Amador and Cabral, 2009).

Compared with the approaches based on international trade statistics, approaches using IO tables reflect the complex relationships among industries and thus provide an appropriate tool for quantifying the degree of VS. A key advantage of using IO tables is that the arbitrariness of dividing goods into 'intermediate' goods and 'final' goods is avoided (Amador and Cabral, 2009). Besides, IO tables also allow us to derive the VS of a single sector (Hummels et al., 2001). Based on IO data, some literature directly uses the intermediate imports to obtain the degree of VS. For example, Feenstra and Hanson (1996, 1999) use the share of imported intermediate inputs in an industry's total non-energy input purchases to measure the outsourcing level. However, this method cannot distinguish whether the intermediate imports are used for domestic production or for producing exports, which will affect the measurement of the VS.

By now, the most popular approach to measure the VS based on IO tables is the HIY method proposed by Hummels et al. (2001). It measures the value of the total imports necessary to produce one unit (e.g. a dollar) of exports. The HIY method has been extended into two directions. The first is the extension of using national input–output (NIO) tables to the multi-country input–output (MRIO) tables. Koopman et al. (2014) measure the VS by separately calculating the foreign value added in the intermediate goods exports of a country, in the final goods exports of this country, and in the double-counted terms.[8] The second extension was developed because the HIY method gave very biased estimates for China's VS share due to the prevalence of processing exports (Dean et al., 2011; Koopman et al., 2012; Yang et al., 2015). For example, Yang et al. (2015) constructed the tripartite IO table that distinguishes between: production for domestic use; production of processing exports; and production of nonprocessing exports and other production of FIEs. They showed that adapting the HIY approach for the tripartite IO table offers more accurate estimates for China's VS share than applying HIY to the standard IO table. Therefore, this paper will adopt the tripartite IO tables. As a robustness check, we will also apply the original HIY approach to standard NIO tables, and apply the method in Koopman et al. (2014) to MRIO tables.

2.2. The traditional HIY method

The traditional HIY method is applied to a standard NIO table with n industries. The $n \times n$ matrix **A** gives the domestic input coefficients, with element a_{ij} indicating the output from

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[8] 'Double-counted terms' in Koopman et al. (2014) refers to the trade value that is accounted by customs more than once due to multiple border crossing of intermediate goods.

industry i that is used as intermediate input by industry j per unit of its output. The matrix with import coefficients is given by $\mathbf{A}^M$ and its element a_{ij}^m denotes the imports of good i used as intermediate input by industry j per unit of its output. Here, $\mathbf{e}$ is the column vector of industry exports. Let $\mathbf{u}$ denote the summation vector, i.e. $\mathbf{u} = (1, \ldots, 1)'$, where a prime is used to indicate transposition of a vector or matrix. Then, according to Hummels et al. (2001), the direct VS share for total exports is formulated as:

$$dvs = \frac{\mathbf{u}'\mathbf{A}^M\mathbf{e}}{\mathbf{u}'\mathbf{e}}. \tag{1}$$

However, export production requires not only imported inputs (i.e. the direct effect), but also domestic inputs, whose production requires imported inputs (i.e. the indirect effects). The total amount of imports that are necessary to produce the vector of exports includes both the directly and the indirectly imported inputs. It is measured by employing the Leontief inverse $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$, where $\mathbf{I}$ is the identity matrix of appropriate dimension. The total VS share for exports is given by:

$$vs = \frac{\mathbf{u}'\mathbf{A}^M\mathbf{L}\mathbf{e}}{\mathbf{u}'\mathbf{e}}. \tag{2}$$

Deducting the direct VS share from the total VS share yields the indirect VS share, which reflects the imports indirectly required for the exports. Throughout the rest of this paper, the term VS share will indicate the total VS share.

2.3. The tripartite method

Before we outline the method of Yang et al. (2015), we provide a brief description of China's tripartite IO table. The tripartite table is an extension of the standard NIO table where production is divided into the following three types. Production of DEs to satisfy domestic demand (indicated by D), production for processing exports (indicated by P), and the combination of production for nonprocessing exports and production of FIEs to meet domestic needs (indicated by N). The form of the tripartite table is shown in Table 1.

Table 1. The schematic outline of China's tripartite input–output table.

	Intermediate use			Final use		
	D	P	N	DFD	EXP	TOT
D	$\mathbf{Z}^{DD}$	$\mathbf{Z}^{DP}$	$\mathbf{Z}^{DN}$	$\mathbf{f}^D$	0	$\mathbf{x}^D$
P	0	0	0	0	$\mathbf{e}^P$	$\mathbf{x}^P$
N	$\mathbf{Z}^{ND}$	$\mathbf{Z}^{NP}$	$\mathbf{Z}^{NN}$	$\mathbf{f}^N$	$\mathbf{e}^N$	$\mathbf{x}^N$
IMP	$\mathbf{Z}^{MD}$	$\mathbf{Z}^{MP}$	$\mathbf{Z}^{MN}$	$\mathbf{f}^M$	0	$\mathbf{x}^M$
VA	$(\mathbf{v}^D)'$	$(\mathbf{v}^P)'$	$(\mathbf{v}^N)'$			
TOT	$(\mathbf{x}^D)'$	$(\mathbf{x}^P)'$	$(\mathbf{x}^N)'$			

Notes: D = production by domestic enterprises (DEs) for domestic use only; P = production of processing exports; N = production of nonprocessing exports and production of FIEs to meet domestic demand; DFD = domestic final demands; EXP = exports; TOT = gross industry outputs (and total imports in the row IMP); IMP = imports; and VA = value added. The IO table is expressed in monetary units. $\mathbf{Z}^{ST}$ indicates the intermediate deliveries from each sector in production type S ($= D, N$) to each sector in production type T ($= D, P, N$). $\mathbf{v}^T$ gives the value added of each sector in production type T, while $\mathbf{x}^T$ gives the output of each sector in production type T. Finally, $\mathbf{f}^T$ gives each sector's products in production type T used for domestic final demand purposes.

The domestic input matrix and the Leontief inverse now become partitioned $3n \times 3n$ matrices

$$\mathbf{A} = \begin{pmatrix} \mathbf{A}^{DD} & \mathbf{A}^{DP} & \mathbf{A}^{DN} \\ 0 & 0 & 0 \\ \mathbf{A}^{ND} & \mathbf{A}^{NP} & \mathbf{A}^{NN} \end{pmatrix} \quad \text{and} \quad \mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \begin{pmatrix} \mathbf{L}^{DD} & \mathbf{L}^{DP} & \mathbf{L}^{DN} \\ 0 & \mathbf{I} & 0 \\ \mathbf{L}^{ND} & \mathbf{L}^{NP} & \mathbf{L}^{NN} \end{pmatrix},$$

where, for example, element a_{ij}^{DP} (of $\mathbf{A}^{DP}$) indicates the output from industry i of D that is used as intermediate input in the industry j that produces P (per unit of its output). Notice that products of P are never used for domestic use by definition, and, therefore the partitions of their intermediate use are zero (i.e. $\mathbf{A}^{PD} = \mathbf{A}^{PP} = \mathbf{A}^{PN} = 0$). The import matrix and export vector become $\mathbf{A}^M = (\mathbf{A}^{MD} \quad \mathbf{A}^{MP} \quad \mathbf{A}^{MN})$ and $\mathbf{e} = \begin{pmatrix} 0 \\ \mathbf{e}^P \\ \mathbf{e}^N \end{pmatrix}$, where, for example, $\mathbf{A}^{MP}$ indicates the import coefficients of the production of P. $\mathbf{e}^P$ and $\mathbf{e}^N$ are the vectors of processing exports and of nonprocessing exports. Note that $\mathbf{e}^D = 0$ because products of D are only for domestic use. In the same fashion, we have in the tripartite table that $\mathbf{f}^P = 0$ because P producers are only allowed to produce exports and do not deliver anything domestically.

Then according to Yang et al. (2015), the direct VS share and the total VS share in the tripartite table can be formulated as:

$$dvs = \frac{\mathbf{u}'\mathbf{A}^M\mathbf{e}}{\mathbf{u}'\mathbf{e}} = \frac{\mathbf{u}'\mathbf{A}^{MP}\mathbf{e}^P + \mathbf{u}'\mathbf{A}^{MN}\mathbf{e}^N}{\mathbf{u}'\mathbf{e}^P + \mathbf{u}'\mathbf{e}^N}; \tag{3}$$

$$vs = \frac{\mathbf{u}'\mathbf{A}^M\mathbf{L}\mathbf{e}}{\mathbf{u}'\mathbf{e}} = \frac{\mathbf{u}'\mathbf{A}^{MD}(\mathbf{L}^{DP}\mathbf{e}^P + \mathbf{L}^{DN}\mathbf{e}^N) + \mathbf{u}'\mathbf{A}^{MP}\mathbf{e}^P + \mathbf{u}'\mathbf{A}^{MN}(\mathbf{L}^{NP}\mathbf{e}^P + \mathbf{L}^{NN}\mathbf{e}^N)}{\mathbf{u}'\mathbf{e}^P + \mathbf{u}'\mathbf{e}^N}. \tag{4}$$

Furthermore, by using counterfactual cases, one can also calculate the VS share for processing and nonprocessing exports separately. For example, if all the nonprocessing exports $\mathbf{e}^N$ are set to zero, then Equation 4 yields the VS share of processing exports.

Note that the only difference between the traditional HIY method and the tripartite method is that they are implemented with different IO tables. However, this difference can result in great gaps in the estimates of the VS shares. Yang et al. (2015) found that estimates of the VS share based on the tripartite method were almost 50% larger than those from the HIY method.[9]

3. Estimation of China's annual VS shares

In this section, we calculate China's VS shares by applying the tripartite method. However, currently, there are only three tripartite tables available. They are for the benchmark years 2002, 2007, and 2012 and were jointly compiled by China's National Bureau of Statistics (NBS) and the Chinese Academy of Sciences (CAS).[10] Equation 4 yields the VS shares,

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[9] Yang et al. (2015) compared the VS shares between the traditional HIY method (applied to the aggregated tripartite tables) and the tripartite method. They also showed that the traditional HIY results are equivalent to a weighted average of the VS shares of the three types of production in the tripartite table, weighted by their output shares (instead of their export shares). As domestic production has a very large share in gross output, its low import dependence then leads to the underestimation of the VS share when the traditional HIY method is applied.

[10] See Lau et al. (2010) and Chen et al. (2012) for compilation details. It is worth noting that in line with the System of National Accounts 2008, only the processing fees of P&A activities are included in the outputs and exports in the official NIO tables

which are 44.9% in 2002, 40.9% in 2007, and 33.1% in 2012.[11] Although these results suggest a trend of declining VS shares, care should be taken because this conclusion is based on only three observations. It is possible that the VS share always fluctuated around the same value but still shows a decrease between 2002 and 2007 and between 2007 and 2012. A more detailed examination of the time pattern of China's VS share requires a series of annual estimates.

To this end, we have roughly constructed the tripartite tables for non-benchmark years based on customs trade data, industrial statistics, and the tripartite tables in benchmark years, and then calculate the VS shares by using Equation 4. However, due to space limit, the full estimation procedure for VS shares in non-benchmark years is given in Appendix A (supplementary material). It is worth to note that due to a lack of data, we only estimate the VS shares of merchandise trade for non-benchmark years. Ignoring trade in services will not affect our findings very much for the following two reasons. First, Chinese trade is dominated by trade in merchandise, which accounts for about 90% of total trade value. Second, by definition, processing trade only exists in merchandise trade. For trade in services, it is therefore unnecessary to distinguish processing trade from nonprocessing trade.

Figure 1 presents our estimates of China's VS shares based on the tripartite tables – indicated by 'Tripartite estimates (excluding services)' – from 2000 to 2012. The estimates show that China's VS share rose from 2001 to 2004, albeit slowly, with an average annual growth rate of 1.3%. It reached a peak of 52.0% in 2004 and then began to slide downwards, declining on average by 1.8% annually from 2005 to 2012.

In the benchmark years, our tripartite estimates for merchandise exports (i.e. excluding services) are close to but slightly higher than the results for all exports (including services). As a comparison, we have also applied the HIY method to China's standard NIO tables. These are derived by aggregating the three production types in the tripartite tables, which are available only for the benchmark years (HIY estimates). The HIY estimates (in Figure 1) are significantly lower than the tripartite estimates (including services). This outcome is fully consistent with the findings of Dean et al. (2011) and Yang et al. (2015) that using NIO tables leads to biased estimates for the VS share. In contrast to the tripartite estimates that show decreasing VS shares, the HIY estimates remained about constant between 2002 and 2012. This further indicates the importance of separating the processing exports from other production.

As a robustness check, we have estimated China's VS shares by using the NIO tables and MRIO tables from the World Input–Output Databases (WIOD) and the OECD-TiVA

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in and after 2007, while the imported materials (P&A imports) are not. However, in the tripartite tables, all imports for processing exports are recorded as intermediate inputs of the processing industry, to reflect its underlying technology. Subtracting the P&A imports from the corresponding items in the tripartite table makes the table almost consistent with the official NIO table. The tripartite tables are different from the IO tables in Ma et al. (2015) and Jiang et al. (2015a, 2015b), which distinguish four types of production: processing exports of DEs, other production of DEs, processing exports of FIEs, other production of FIEs. Since Ma et al. (2015) show that the VS share of exports of DEs within the same trade mode (e.g., processing trade, nonprocessing trade) is very close to that of FIEs. Therefore, our tripartite IO tables, which only separate the processing exports from other production, are enough to provide accurate estimates of VS share in China.

[11] The results in 2002 and 2007 for all exports have also been reported in Yang et al. (2015). Also, Koopman et al. (2012) used IO tables that singled out processing exports and found VS shares of 46.1% in 2002 and 39.4% in 2007. The differences between the findings of Koopman et al. (2012) and ours are due to the different methods of separating processing exports from other production. Our tripartite tables rely heavily on survey data, while the bipartite tables of Koopman et al. (2012) rely more on quadratic programming.

Figure 1. Estimates of China's VS shares from 2000 to 2012.
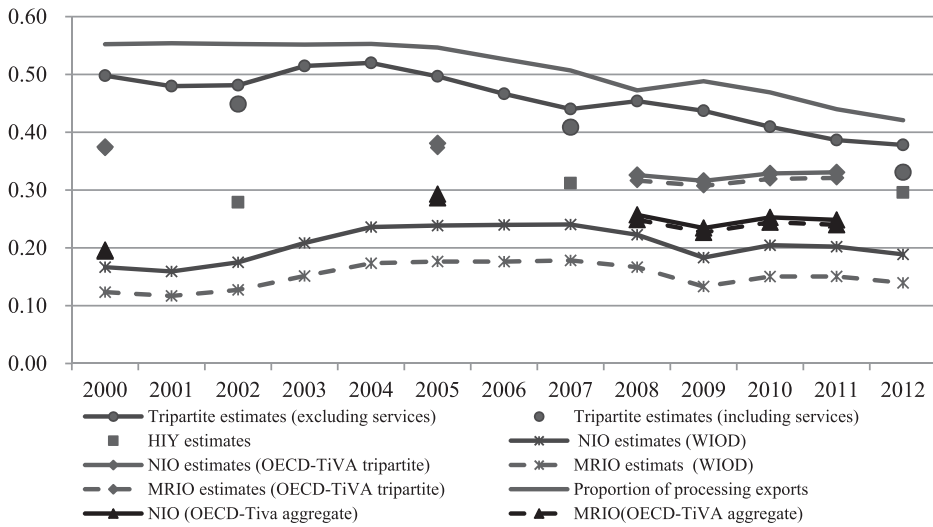
database (WIOD estimates and OECD-TiVA tripartite estimates, respectively). Equation 2 has been applied to the NIO tables and the method in Koopman et al. (2014) to the MRIO tables.[12] Except for coving different time periods, another significant difference between WIOD and OECD-TiVA is that the OECD-TiVA tables separate China's production of processing exports from other production, whilst WIOD tables do not.[13] For a clear comparison, we also re-estimate the VS shares by firstly aggregating the processing exports and nonprocessing production together in OECD-TiVA IO tables (OECD-TiVA aggregate estimates, hereafter).

The results in Figure 1 all indicate a decline of China's VS share in recent years. The WIOD estimates are in line with the tripartite estimates and show that the VS share first increased gradually and slowly declined after 2006 (except for the additional dip in 2009).[14] Both OECD-TiVA tripartite estimates and OECD-TiVA aggregate estimates show similar trends with WIOD estimates, although with fewer observations. However, the OECD-TiVA aggregate estimates are much lower than OECD-TiVA estimates. This further verified our results that the IO tables which fail to separate processing exports from other productions will seriously underestimate the China's VS share. Still, some other differences are observed between the levels of the VS shares for the various estimates. Though all tables

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[12] Koopman et al. (2014) argue that for MRIO models the VS share of country s can be calculated as $(\mathbf{c}'_s \mathbf{B}_{ss} \mathbf{e}_s)/(\mathbf{u}' \mathbf{e}_s)$, where $\mathbf{c}'_s$ is the row vector of value-added coefficients of country s, $\mathbf{e}_s$ is the column vector of exports in country s, $\mathbf{B}_{ss}$ is the partition of the Leontief inverse $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$ that corresponds to country s, where $\mathbf{A}$ is the world intermediate input coefficient matrix.

[13] WIOD provides annual tables that cover the entire period 2000–2012 (Dietzenbacher et al., 2013) but the OECD-TiVA tables are (in this period) only available for 2000, 2005, and 2008–2011.

[14] The dip may have been caused by the global financial crisis in 2008, which resulted in a collapse of global trade. As Bems et al. (2011) documented, the decline in demand during the crisis was the largest in sectors with a large vertical specialization. As a result, the VS share decreased rapidly in 2009 and recovered slightly in 2010. Johnson and Noguera (2016) found that the VAX ratio (i.e., the ratio of value-added exports to gross exports) for China steadily increased from 2005 to 2010. Their results imply a steady decrease of foreign value added in China's exports during this period, which is entirely in line with our tripartite estimates.

(WIOD, OECD-TiVA, and tripartite) used the official NBS IO tables as underlying data, they have been adapted in a different way and therefore yield different results.

Figure 1 also shows that the MRIO estimates are always very similar but slightly lower than the NIO estimates from the same database. The possible reason is that compared with the NIO estimates, the MRIO estimates exclude the domestic content that returns to the source country.[15] Nevertheless, both estimates show similar trends over time.

The continuous decline of VS shares in China is somewhat surprising. The deepening of international fragmentation implies that cross-border supply chains have become more prevalent and production has become more dependent on imported intermediates. It seems that in recent years China is an exception to the global tendency of countries participating more and more actively in globalization. In past decades, China's low labor and land costs have generated large amounts of labor-intensive processing activities. As a result, China became the famous 'world's factory'. Parts and components were imported and re-exported again after very simple assembling or processing activities had been conducted. However, the declining VS share points to a change in this situation. To better understand the implications of the declining VS share, we will investigate the underlying drivers of this decrease in the next section.

4. Decomposition of the VS share

Several factors are expected to have contributed to the decline of the VS share. On the one hand, Figure 1 shows similarities in the trends of the VS share and the processing exports share. This suggests that the decreasing share of processing exports (with large import dependence) may be the main driver of the decreasing VS shares. If so, the decreasing VS shares simply suggest that the 'world's factory' is moving out of China. On the other hand, the decreasing VS shares may be caused by changes in the input structure. The production of exports has become less dependent on imports and relies, instead, more on domestic inputs. In this case, decreasing VS shares suggest that China's role in the GVCs has been upgraded. The tripartite IO table distinguishes three types of production: D (DEs production to satisfy domestic demand), P (production for processing exports), and N (production for nonprocessing exports and production of FIEs to meet domestic needs). It allows us to investigate how much each type of production contributed to the decline of China's VS share. Answering this question not only provides insight into the pattern of China's economic development, but also has important policy implications. This is because upgrading China's role in the GVCs is an important target clearly indicated in the country's 10-year national plan 'Made in China 2025'.

To answer the question how much each type of production contributed to the decline of China's VS share, we develop a new decomposition. It splits the change in the VS share into the contributions by each of its 14 drivers. The new decomposition allows us to capture the contribution to the VS share change of different production types as well as of substitutions among different inputs. The decomposition enables us to provide a detailed analysis of the pattern of China's economic development.

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[15] See Koopman et al. (2014) for details.

4.1. A brief introduction to structural decomposition analysis

We start this subsection with a brief description of SDA, which has been widely used to break down the change in one variable into the changes of its independent determinants. Decompositions are not unique. In the case of n independent determinants, the number of equivalent decompositions is $n!$. Because it is computationally burdensome to calculate all of the $n!$ decompositions, several shortcuts have been proposed.[16] Among them, Dietzenbacher and Los (1998) suggest using the average of the two so-called polar decompositions, and they show that this average provides a good approximation of the average of all $n!$ decompositions.

The idea of two polar decompositions can be illustrated by using an SDA model with two determinants as an example. That is, $\mathbf{y} = \mathbf{Bf}$, where $\mathbf{B}$ and $\mathbf{f}$ can change independently from each other. Subscripts 0 and 1 denote the beginning year and the end year. The change in $\mathbf{y}$ can then be ascribed to the changes in $\mathbf{B}$ and $\mathbf{f}$ as follows:

$$\Delta\mathbf{y} = \mathbf{B}_1\mathbf{f}_1 - \mathbf{B}_0\mathbf{f}_0$$

$$= \mathbf{B}_1\mathbf{f}_1 - \mathbf{B}_1\mathbf{f}_0 + \mathbf{B}_1\mathbf{f}_0 - \mathbf{B}_0\mathbf{f}_0 = \mathbf{B}_1(\Delta\mathbf{f}) + (\Delta\mathbf{B})\mathbf{f}_0 \text{ (one polar)} \tag{5a}$$

$$= \mathbf{B}_1\mathbf{f}_1 - \mathbf{B}_0\mathbf{f}_1 + \mathbf{B}_0\mathbf{f}_1 - \mathbf{B}_0\mathbf{f}_0 = \mathbf{B}_0(\Delta\mathbf{f}) + (\Delta\mathbf{B})\mathbf{f}_1 \text{ (counter polar)} \tag{5b}$$

$$= 0.5(\Delta\mathbf{B})(\mathbf{f}_0 + \mathbf{f}_1) + 0.5(\mathbf{B}_0 + \mathbf{B}_1)(\Delta\mathbf{f}). \text{ (average)} \tag{5c}$$

Equations 5a and 5b are the polar decompositions using different weights, and Equation 5c takes the average of the two polar decompositions and provides the final result.

4.2. Overall decomposition of the changes in the VS share

To derive the decomposition formula for VS share, we start with Equation 4. Among the determinants are the matrices with import coefficients ($\mathbf{A}^M$) and with domestic input coefficients ($\mathbf{A}$). Although they are not fully dependent on each other, they are very closely related.[17] First, intermediate inputs are determined by factors such as the level of primary inputs and the production technology. This holds for import and for domestic input coefficients. Second, there is sufficient evidence for the substitution of imported and domestically produced intermediates (e.g. Kee and Tang, 2016). In order to solve this dependency problem, the input structure will be decomposed into four parts: substitution between primary and intermediate inputs (e.g. greater amounts of capital increased the efficiency of production, so that fewer intermediates are required per unit of output), substitution between intermediate inputs (e.g. replacing steel with plastic), substitution between imported and domestically produced intermediates, and substitution between domestically produced intermediates provided by DEs and by FIEs.

$\mathbf{A}^T = \mathbf{A}^{D*} + \mathbf{A}^{N*} + \mathbf{A}^M$ (with $n \times 3n$ dimension) indicates the total input coefficients (i.e. the total amount of intermediate inputs required per unit of output, irrespective of their

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[16] For example, Sun (1998) and Sun and Ang (2000) propose to split the interaction terms equally over the determinants. His approach yields exactly the same results as the average of the $n!$ different outcomes, which was proposed by Dietzenbacher and Los (1998).

[17] According to Dietzenbacher and Los (2000), full dependency occurs if one determinant cannot change without corresponding changes in another determinant.

source), with $\mathbf{A}^{D*} = (\mathbf{A}^{DD} \quad \mathbf{A}^{DP} \quad \mathbf{A}^{DN})$ and $\mathbf{A}^{N*} = (\mathbf{A}^{ND} \quad \mathbf{A}^{NP} \quad \mathbf{A}^{NN})$ indicating the input coefficients of intermediates sourced from DEs and from FIEs. Note that the production for processing exports does not deliver anything domestically. Further, we define $\mathbf{A}^{H} = \mathbf{A}^{D*} + \mathbf{A}^{N*}$ (with $n \times 3n$ dimension) for the aggregate domestic input coefficients.

We denote the value-added ratios by c_j. Then, there is full dependency because

$$\mathbf{u}'\mathbf{A}^{T} = \mathbf{u}' - \mathbf{c}'. \tag{6}$$

The changes in $\mathbf{c}'$ reflect the substitution between primary inputs and intermediate inputs. Following Equation 6, we rewrite $\mathbf{A}^{T}$ as the product of its level and its structure:

$$\mathbf{A}^{T} = \mathbf{A}^{K}(\mathbf{I} - \hat{\mathbf{c}}), \tag{7}$$

where $\mathbf{A}^{K} = \mathbf{A}^{T}(\mathbf{I} - \hat{\mathbf{c}})^{-1}$ is the matrix with normalized total intermediate input coefficients. They provide the mix of intermediate inputs in each industry. Changes in $\mathbf{A}^{K}$ therefore represent the inter-sector substitution between intermediate inputs.

To distinguish between imported and domestically produced intermediates, we introduce the $n \times 3n$ matrix $\mathbf{R}$ with the share of imports in total intermediates. That is, $r_{ij} = a_{ij}^{M}/a_{ij}^{T}$. We then have

$$\mathbf{A}^{M} = \mathbf{A}^{T} \otimes \mathbf{R}, \tag{8}$$

where the Hadamard product $\otimes$ indicates cell-by-cell multiplication. The changes in $\mathbf{R}$ represent the substitution between imports and domestic intermediates. For example, an increase in the elements of $\mathbf{R}$ implies a substitution of domestically produced intermediates by imported intermediates. In the same way, we have the matrix with domestic input coefficients

$$\mathbf{A}^{H} = \mathbf{A}^{T} - \mathbf{A}^{M} = \mathbf{A}^{T} \otimes (\mathbf{U} - \mathbf{R}), \tag{9}$$

where $\mathbf{U}$ is a $n \times 3n$ matrix with all elements equal to 1.

Domestic intermediates ($\mathbf{A}^{H}$) are provided by DEs ($\mathbf{A}^{D*}$) or by FIEs ($\mathbf{A}^{N*}$). We define the $n \times 3n$ matrix $\mathbf{S}$ as follows $s_{ij} = a_{ij}^{D*}/a_{ij}^{H}$, which gives the shares of domestic intermediates that are provided by DEs. Combining with Equation 9, we have

$$\mathbf{A}^{D*} = \mathbf{A}^{H} \otimes \mathbf{S} = \mathbf{A}^{T} \otimes (\mathbf{U} - \mathbf{R}) \otimes \mathbf{S}, \tag{10}$$

$$\mathbf{A}^{N*} = \mathbf{A}^{H} - \mathbf{A}^{D*} = \mathbf{A}^{T} \otimes (\mathbf{U} - \mathbf{R}) \otimes (\mathbf{U} - \mathbf{S}). \tag{11}$$

The changes in $\mathbf{S}$ measure the substitution between intermediate inputs provided by DEs and FIEs. An increase in $\mathbf{S}$ indicates a substitution of FIE products with DE products. Together with $\mathbf{R}$, $\mathbf{S}$ sheds further light on the substitution of imports and products of DEs and FIEs. For example, a simultaneous decline in $\mathbf{R}$ and $\mathbf{S}$ implies that FIE products, rather than DE products, have been substituted by imported intermediate inputs.

Substituting Equations 7, 8, 10, and 11 into Equation 4 yields

$$vs = \mathbf{u}'(\mathbf{A}^T \otimes \mathbf{R}) \left[\mathbf{I} - \begin{pmatrix} \mathbf{A}^{D*} \\ 0 \\ \mathbf{A}^{N*} \end{pmatrix} \right]^{-1} \bar{\mathbf{e}}$$

$$= \mathbf{u}'\{[\mathbf{A}^K(\mathbf{I} - \hat{\mathbf{c}})] \otimes \mathbf{R}\} \left\{ \mathbf{I} - \begin{pmatrix} [\mathbf{A}^K(\mathbf{I} - \hat{\mathbf{c}})] \otimes (\mathbf{U} - \mathbf{R}) \otimes \mathbf{S} \\ 0 \\ [\mathbf{A}^K(\mathbf{I} - \hat{\mathbf{c}})] \otimes (\mathbf{U} - \mathbf{R}) \otimes (\mathbf{U} - \mathbf{S}) \end{pmatrix} \right\}^{-1} \bar{\mathbf{e}}, \quad (12)$$

where $\bar{\mathbf{e}} = \mathbf{e}/(\mathbf{u}'\mathbf{e})$ gives the vector with the export structure. Equation 12 expresses the VS share as a function of five independent determinants. To summarize, changes in $\mathbf{A}^K$ indicate the substitution among intermediate inputs, changes in $\mathbf{c}$ represent the substitution between intermediate inputs and primary inputs, changes in $\mathbf{R}$ represent the substitution between imported and domestically produced intermediates, and changes in $\mathbf{S}$ indicate the substitution between intermediates provided by FIEs and DEs. These four components reflect changes in the input structure of production. Finally, changes in $\bar{\mathbf{e}}$ are export composition changes.

4.3. Decomposing the VS share by production type

In order to examine how much each of the three production types (D, P, and N) contributes separately to the change in the VS share, we split Equation 12. For the $3n$-element vector $\mathbf{c}'$ we have $\mathbf{c}' = ((\mathbf{c}^D)' \quad (\mathbf{c}^P)' \quad (\mathbf{c}^N)')$. Similarly, for the following $n \times 3n$ matrices, we have $\mathbf{A}^K = (\mathbf{A}^{KD} \quad \mathbf{A}^{KP} \quad \mathbf{A}^{KN})$, $\mathbf{R} = (\mathbf{R}^D \quad \mathbf{R}^P \quad \mathbf{R}^N)$, and $\mathbf{S} = (\mathbf{S}^D \quad \mathbf{S}^P \quad \mathbf{S}^N)$. This yields for Equation 12,

$$[\mathbf{A}^K(\mathbf{I} - \hat{\mathbf{c}})] \otimes \mathbf{R} = \left(\mathbf{A}^{KD}(\mathbf{I} - \hat{\mathbf{c}}^D) \otimes \mathbf{R}^D \quad \mathbf{A}^{KP}(\mathbf{I} - \hat{\mathbf{c}}^P) \otimes \mathbf{R}^P \quad \mathbf{A}^{KN}(\mathbf{I} - \hat{\mathbf{c}}^N) \otimes \mathbf{R}^N \right),$$
$$(13)$$

and

$$\begin{pmatrix} \mathbf{A}^{D*} \\ 0 \\ \mathbf{A}^{N*} \end{pmatrix} = \begin{pmatrix} \Omega^{DD} & \Omega^{DP} & \Omega^{DN} \\ 0 & 0 & 0 \\ \Omega^{ND} & \Omega^{NP} & \Omega^{NN} \end{pmatrix}, \quad (14)$$

with, for example, $\Omega^{DP} = \mathbf{A}^{KP}(\mathbf{I} - \hat{\mathbf{c}}^P) \otimes (\mathbf{U} - \mathbf{R}^P) \otimes \mathbf{S}^P$ and $\Omega^{NP} = \mathbf{A}^{KP}(\mathbf{I} - \hat{\mathbf{c}}^P) \otimes (\mathbf{U} - \mathbf{R}^P) \otimes (\mathbf{U} - \mathbf{S}^P)$.

We can now ascribe the change in the VS share into the contribution of the changes in 13 independent components. These are: the structure of intermediate inputs for each of the three production types ($\mathbf{A}^{KD}$, $\mathbf{A}^{KP}$, and $\mathbf{A}^{KN}$), the value-added ratios ($\mathbf{c}^D$, $\mathbf{c}^P$, and $\mathbf{c}^N$), the shares of imported intermediates ($\mathbf{R}^D$, $\mathbf{R}^P$, and $\mathbf{R}^N$), the shares of the domestic intermediates provided by DEs ($\mathbf{S}^D$, $\mathbf{S}^P$, and $\mathbf{S}^N$), and the export structure ($\bar{\mathbf{e}}$).

Note that our decomposition fails to disentangle the effect of changes in the export structure $\bar{\mathbf{e}}$ by production type. Because the structure is defined in terms of export shares, $\bar{\mathbf{e}}^P \equiv \mathbf{e}^P/\mathbf{u}'(\mathbf{e}^P + \mathbf{e}^N)$ and $\bar{\mathbf{e}}^N \equiv \mathbf{e}^N/\mathbf{u}'(\mathbf{e}^P + \mathbf{e}^N)$ are highly dependent on each other, as $\mathbf{u}'\bar{\mathbf{e}}^P + \mathbf{u}'\bar{\mathbf{e}}^N = 1$. We define $t^P = \mathbf{u}'\bar{\mathbf{e}}^P$ as the share of all processing exports in total exports. The share of nonprocessing exports is then given by $1 - t^P$. We further define the commodity mix of processing exports as $\mathbf{q}^P = \bar{\mathbf{e}}^P/t^P$ and the commodity mix of nonprocessing

exports as $\mathbf{q}^N = \bar{\mathbf{e}}^N/(1 - t^P)$. This implies that the export vector can be written as

$$\bar{\mathbf{e}} = \begin{pmatrix} 0 \\ \bar{\mathbf{e}}^P \\ \bar{\mathbf{e}}^N \end{pmatrix} = \begin{pmatrix} 0 \\ t^P\mathbf{q}^P \\ (1 - t^P)\mathbf{q}^N \end{pmatrix}.$$

We would like to split $\bar{\mathbf{e}}$ into just two components: changes in the processing exports and changes in the nonprocessing exports. This implies that the change in t^P must partly be ascribed to changes in processing exports and partly to changes in nonprocessing exports. If the change in t^P is fully ascribed to changes in processing exports we have

$$\Delta\bar{\mathbf{e}} = \left[\begin{pmatrix} 0 \\ t_1^P\mathbf{q}_1^P \\ (1 - t_1^P)\mathbf{q}_1^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_0^P\mathbf{q}_0^P \\ (1 - t_0^P)\mathbf{q}_1^N \end{pmatrix} \right] + \left[\begin{pmatrix} 0 \\ t_0^P\mathbf{q}_0^P \\ (1 - t_0^P)\mathbf{q}_1^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_0^P\mathbf{q}_0^P \\ (1 - t_0^P)\mathbf{q}_0^N \end{pmatrix} \right].$$
(15a)

The first bracketed expression gives the changes in the processing exports and includes the change in t^P, the second bracketed term gives the changes in nonprocessing exports and covers only the changes in $\mathbf{q}^N$. In the same fashion, including the change in t^P in the changes in nonprocessing exports and leaving only the changes in $\mathbf{q}^P$ for the changes in processing exports, yields

$$\Delta\bar{\mathbf{e}} = \left[\begin{pmatrix} 0 \\ t_0^P\mathbf{q}_1^P \\ (1 - t_0^P)\mathbf{q}_0^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_0^P\mathbf{q}_0^P \\ (1 - t_0^P)\mathbf{q}_0^N \end{pmatrix} \right] + \left[\begin{pmatrix} 0 \\ t_1^P\mathbf{q}_1^P \\ (1 - t_1^P)\mathbf{q}_1^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_0^P\mathbf{q}_1^P \\ (1 - t_0^P)\mathbf{q}_0^N \end{pmatrix} \right].$$
(15b)

Note that Equations 15a and 15b are each a 'polar' decomposition, their corresponding 'mirror images' are given in Equations 15c and 15d below.

$$\Delta\bar{\mathbf{e}} = \left[\begin{pmatrix} 0 \\ t_1^P\mathbf{q}_1^P \\ (1 - t_1^P)\mathbf{q}_0^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_0^P\mathbf{q}_0^P \\ (1 - t_0^P)\mathbf{q}_0^N \end{pmatrix} \right] + \left[\begin{pmatrix} 0 \\ t_1^P\mathbf{q}_1^P \\ (1 - t_1^P)\mathbf{q}_1^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_1^P\mathbf{q}_1^P \\ (1 - t_1^P)\mathbf{q}_0^N \end{pmatrix} \right],$$
(15c)

$$\Delta\bar{\mathbf{e}} = \left[\begin{pmatrix} 0 \\ t_1^P\mathbf{q}_1^P \\ (1 - t_1^P)\mathbf{q}_1^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_1^P\mathbf{q}_0^P \\ (1 - t_1^P)\mathbf{q}_1^N \end{pmatrix} \right] + \left[\begin{pmatrix} 0 \\ t_1^P\mathbf{q}_0^P \\ (1 - t_1^P)\mathbf{q}_1^N \end{pmatrix} - \begin{pmatrix} 0 \\ t_0^P\mathbf{q}_0^P \\ (1 - t_0^P)\mathbf{q}_0^N \end{pmatrix} \right].$$
(15d)

The change in processing exports, for example, is obtained as the average of the bracketed terms listed first in Equations 15a–15d.

Summarizing, it follows from Equations 4 and 5 that

$$\Delta vs = \frac{1}{2}\mathbf{u}'[(\Delta(\mathbf{A}^M\mathbf{L}))](\bar{\mathbf{e}}_0 + \bar{\mathbf{e}}_1) + \frac{1}{2}\mathbf{u}'(\mathbf{A}_0^M\mathbf{L}_0 + \mathbf{A}_1^M\mathbf{L}_1)(\Delta\bar{\mathbf{e}}),$$
(16)

when $\Delta\bar{\mathbf{e}}$ is split into two components (changes in processing exports and changes in nonprocessing exports) using Equations 15. $\Delta(\mathbf{A}^M\mathbf{L})$ is split into 12 components ($\mathbf{A}^{KD}$, $\mathbf{A}^{KP}$, $\mathbf{A}^{KN}$, $\mathbf{c}^D$, $\mathbf{c}^P$, $\mathbf{c}^N$, $\mathbf{R}^D$, $\mathbf{R}^P$, $\mathbf{R}^N$, $\mathbf{S}^D$, $\mathbf{S}^P$, and $\mathbf{S}^N$) on the basis of Equations 13 and 14. Details

Table 2. Summary of the components in the structural decomposition analysis.

Effects	The change in VS share due to changes in:
$E(A^{KD})$, $E(A^{KP})$, $E(A^{KN})$	The structure of intermediate inputs in the production of D, P, N
$E(c^D)$, $E(c^P)$, $E(c^N)$	The value-added ratios for the production of D, P, N
$E(R^D)$, $E(R^P)$, $E(R^N)$	The shares of imported intermediate inputs in total intermediate inputs for the production of D, P, N
$E(S^D)$, $E(S^P)$, $E(S^N)$	The shares of domestic intermediate inputs that are provided by DEs in the production of D, P, N
$E(\bar{e}^P)$, $E(\bar{e}^N)$	The structures of processing and nonprocessing exports

Notes: D = production by DEs for domestic use only; P = production of processing exports; N = production of nonprocessing exports and production of FIEs to meet domestic demand.

of the decomposition of $\Delta(\mathbf{A}^M\mathbf{L})$ are given in Appendix B (supplementary material) and Table 2 summarizes the components of the decomposition.

Adding the appropriate components gives us the total effect on the VS share of all of the changes related to each of the three production types That is,

$$E(D) = E(\mathbf{A}^{KD}) + E(\mathbf{c}^D) + E(\mathbf{R}^D) + E(\mathbf{S}^D), \tag{17a}$$

$$E(P) = E(\mathbf{A}^{KP}) + E(\mathbf{c}^P) + E(\mathbf{R}^P) + E(\mathbf{S}^P) + E(\mathbf{e}^P), \tag{17b}$$

$$E(N) = E(\mathbf{A}^{KN}) + E(\mathbf{c}^N) + E(\mathbf{R}^N) + E(\mathbf{S}^N) + E(\mathbf{e}^N). \tag{17c}$$

5. Empirical results

5.1. The aggregate results

This section presents and discusses the results of decomposing the change of China's VS share from 2002 to 2007 and from 2007 to 2012.[18] The main reason we choose these two periods is that they are the most recent years for which full tripartite IO tables are available. Although we also derived tripartite IO tables for all non-benchmark years from 2000 to 2012, they cannot provide the full picture if used in an SDA because the estimation is rather crude due to lack of data. This decomposition also allows us to compare China's trade development before and after the financial crisis. The tripartite tables for the three years include 42 sectors but the sector classifications differ slightly. In order to ensure a consistent sector classification, we aggregated the 42 sectors into 40 sectors (see Appendix C (supplementary material)). A final remark is that the decomposition of the VS share is based on current priced IO tables, because they are the only ones available. Nevertheless, Section 5.4 presents a robustness check of our SDA results using crudely estimated tripartite tables in constant prices.[19]

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[18] Pei et al. (2012) also used the same tripartite tables in their SDA. However, they focus on the contribution of imports on China's GDP growth. Also their decompositions are completely different from ours.

[19] Ideally, one would like to do the SDA with IO tables in constant prices. However, constructing an accurate constant price table requires considerable price information, for example, the price indexes for each transaction between producers as well as from producers to domestic or foreign consumers. Most of the price information is not available at the sectoral level in China. Therefore, estimating tables in constant prices would introduce many new biases as the lack of data requires us to make assumptions, which are somewhat crude. Therefore, we present the current price-based SDA results in the main section. Since all of the components in our decomposition are ratios, we expect that the price change effect is relatively small. Still, we also try our best to compile the constant price IO tables and treat the constant price-based SDA results as robustness check in subsection 5.4.

Table 3. The decomposition of China's VS share (unit: %).

|	2002–2007				2007–2012			
	D	P	N	Sum	D	P	N	Sum
A^K	0.3	0.3	0.9	1.5	0.0	−0.7	−0.6	−1.3
c	1.0	−0.6	−1.2	−0.8	0.1	−0.3	0.5	0.3
R	0.7	−4.5	−3.1	−6.9	0.9	−1.1	−4.1	−4.2
S	0.3	−0.6	0.2	−0.1	0.2	0.1	0.1	0.4
ē	–	1.6	0.7	2.3	–	−0.5	−2.4	−3.0
Sum	2.3	−3.8	−2.5	−4.0	1.2	−2.5	−6.5	−7.8

Notes: D = production by DEs for domestic use only; P = production of processing exports; N = production of nonprocessing exports and production of FIEs to meet domestic demand; DEs = domestic enterprises; FIEs = foreign-invested enterprises.

Table 3 provides the results for the 14 components listed earlier in Table 2. Table 3 also provides the aggregate results for the three types of production (i.e. taking the column sums) and for each factor (i.e. taking the row sums, which reflect a component's contribution over the production types). All of the results are given as absolute changes (i.e. percentage point changes). The VS share decreased by 4.0% from 44.9% in 2002 to 40.9% in 2007 and by 7.8% from 2007 to 33.1% in 2012. However, the reasons for the decreases are different in the two periods.

The results show how the VS share would have changed due to changes in a particular component, assuming all other components would have remained constant. For example, the second row (**c**) in Table 3 indicates that the changes in the value-added ratios of the production of P have decreased the VS share by 0.6%, which equals 15% of the total decrease in the VS share from 2002 to 2007. The changes in all value-added ratios have contributed 20% to the decrease of the VS share (i.e. a decrease of 0.8 percent). The second column sum indicates that all changes in the production of P have decreased the VS share from 2002 to 2007 by 3.8%.

With respect to the aggregate results for the factors, Table 3 shows that the changes in the import shares of intermediate inputs (**R**) played the most important role in the decline of the VS share in both periods. The substitution of imported intermediate inputs by domestically produced inputs has been the main driver of the VS share decline. The second important driver was the changes in the export structure (**ē**), but the contributions to the VS share's change had opposite signs before and after the crisis. The share of the import-intensive processing exports in total exports has declined substantially since 2002 (see Figure 1). One would therefore expect this to cause a decline in China's VS share. However, the changes in export structure have significantly increased, rather than decreased, the VS share in China from 2002 to 2007. The consequence of this finding is that the mix of exported goods must have changed in favor of more import-intensive products. When we combine this information with the analysis in Section 3.2, the decomposition result indicates that the decreasing VS shares suggest an upgrade of China's role in the GVCs, rather than the 'world's factory' moving out of China.

For the different production categories, changes in the production of P are the largest contributor to the decline of the VS share from 2002 to 2007. They are followed by changes in the production of N, which became the largest contributor in the period 2007–2012. It should be noted that more than 80% of the processing exports in China were produced by FIEs and more than 75% of the output of N were domestic products produced by FIEs. As

Figure 2. Aggregate input structure in 2002, 2007, and 2012 (unit: %).
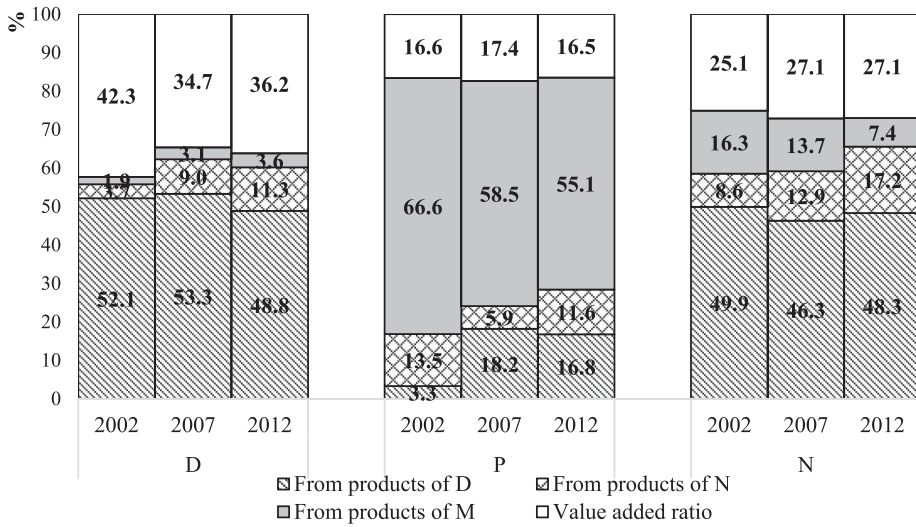
Notes: D = production by DEs for domestic use only; P = production of processing exports; N = production of non processing exports and production of FIEs to meet domestic demand; M = imports.

a consequence, FIEs played a significant role in the decline of China's VS share. The reduction in the VS share brought about by them was partly offset by changes in the production of D. The size of the effect (i.e. an increase in the VS share of 2.3% for 2002–2007 and 1.2% for 2007–2012) is remarkably large, given that the production of D is only indirectly involved in the exports.

5.2. Changes in the input structure

5.2.1. A comparison of the input structures

All of the factors listed in Table 3, except the export structure, reflect changes in the input structure of Chinese production. Figure 2 gives the aggregate input structures (i.e. all 40 industries have been aggregated into one) in 2002, 2007, and 2012 for each production type. These average input coefficients show how the direct deliveries among different production types have changed. For example, the production of 100 Rmb N required in 2012, on average, 48.3 Rmb of inputs from products of D, 17.2 Rmb of inputs from products of N, 7.4 Rmb of imports, and generated 27.1 Rmb of value added.

The Chinese input structure shows several characteristics. First, huge differences exist between the three production types. The value-added ratio of D is much higher than that of N, which in turn is larger than that of P. Second, when it comes to the use of imported inputs the opposite situation occurs. The production of P has an extremely high dependence on imported intermediates, while production of D and N does not. This implies that production of D and N largely depends on domestically produced intermediate inputs, which are produced by DEs as shown by 'From products of D' and by FIEs as shown by 'From products of N', as witnessed in Figure 2.

Looking at the input structure, several substantial changes have taken place over time. This particularly holds for the production of *P* and *N*. Their input structures show large shifts from using imported intermediates toward using domestic intermediates in both periods. However, the shift is more toward inputs produced by DEs in the production of *P* and more to inputs produced by FIEs in the production of *N*. The share of inputs from DEs (i.e. from *D*) in the production of *P* has increased rapidly from 3.3% in 2002 to 18.2% in 2007, and then fallen slightly to 16.8% in 2012. The share of inputs from FIEs (i.e. from *N*) in the production of *N* has increased from 8.6% in 2002 to 12.9% in 2007 and then to 17.2% in 2012. In contrast, the production of *D* shifted from using primary inputs to using intermediate inputs, especially intermediates provided by FIEs and imports.

5.2.2. *Substitution of imported intermediates by domestically produced inputs*

We have seen that changes in the shares of imported intermediates (**R**) are the main contributor to the decline of China's VS share. If only **R** had changed as it actually did and everything else had remained constant, China's VS share would have dropped by 6.9% from 2002 to 2007 and by 4.2% from 2007 to 2012. Imported intermediates have been substituted by domestic intermediates, which is the main driver of China's declining VS share. This finding resonates with the conclusion of Kee and Tang (2016). Using firm-level data from 2000 to 2007, they find a within firm substitution of imported materials by domestically produced materials. As we see in Table 3 and Figure 2, the case is very clear for the production of *P* and *N*, which led to a decrease in the VS share of $4.5 + 3.1 = 7.6\%$ from 2002 to 2007 and of $1.1 + 4.1 = 5.2\%$ from 2007 to 2012.

Then, another intriguing question is whether the imports are substituted by products of DEs or those of FIEs. Theories on international trade yield different outcomes and, depending on the reasoning, state that imported materials are substituted by products from FIEs or from DEs. On the one hand, according to Mundell (1957), foreign direct investment (FDI) is a substitute for imports. Certain products that were originally imported are now produced by FIEs in the host country. In this case, the substitution of imports by domestic intermediates is just a direct consequence of foreign producers shifting their plant locations (Pugel, 2012). On the other hand, substitution of imports by DEs' products occurs when DEs improve their production technology and product quality. This may happen, for example, through technology spillovers from FDI or increased R&D investments (Liu, 2008; Wang, 2014).

The first line of reasoning hypothesizes that imports are substituted by domestic products of FIEs. The second line arrives at the substitution of imported intermediates with domestic products by DEs.

For the production of *P*, Table 3 shows that the change in the shares of inputs provided by DEs in total domestic intermediates (**S**) has decreased the VS share by 0.6% from 2002 to 2007. Given the fact that the production of *N* typically depends more on imports than the production of *D*, this decomposition result reveals that the imported intermediates are mainly substituted by DEs' products in the production of *P* from 2002 to 2007. In the period 2007 to 2012, the change in **S** has increased the VS share by 0.1%. A similar line of reasoning suggests that imported intermediates have been mainly substituted with FIEs' products (i.e. from *N*) from 2007 to 2012. For the production of *N*, the imports are mainly substituted by FIEs' products in both periods. All of our findings are confirmed by Figure 2. Returning to the theories, the results for the production of *P* are in line with the upgrading

of DEs' products. The results for the production of *N* are in line with a larger role of FIEs in supplying intermediates on the domestic market. This stronger role of FIEs is also related to the FIEs' market strategy, which shows a shift from exports to sales in China's domestic market. Figures from the NBS state that the share of domestic sales in FIEs' manufacturing output has increased from 58.6% in 2007 to 70.3% in 2015.

The tripartite tables also provide detailed sectoral input information for each production type, which allows us to further investigate which kind of imported inputs are substituted in export production. It shows that over the period 2002–2007, imported intermediates across all manufacturing products are partially substituted by products of DEs for the production of *P*. Manufacture imports except imports of *Non-metallic mineral products* (13), *Metals smelting and pressing* (14), *Metal products* (15), are partially substituted by products of DEs and FIEs in the production of N from 2002 to 2007. From 2007 to 2012, in export production, the substitution mainly focuses on the imports of *Manufacture of food products and tobacco processing* (6), *Chemicals* (12), *Non-metallic mineral products* (13), and *Equipment and machinery* (16–20), which are partially substituted by the intermediates provided by DEs as well as FIEs.

Overall, our decomposition shows that China's decreasing VS share is largely a combination of DEs' product upgrading and expansions of FIEs in the domestic market. As Duan et al. (2012) documented, a large part of FIEs' profits do not belong to national income. China should therefore focus particularly on improving the competitiveness of intermediates provided by DEs. Our results also imply an increase in the competiveness of domestic products, which contributed significantly to China's upgrading in the GVCs. As the existing literature shows, this may be highly related with China's increasing Research and Development (R&D) investment (Wang, 2014), increasing human capital (Li et al., 2013), and the spillover effect of the FDI to DEs (Liu, 2008; Zhang, 2014).

5.3. The export structure

Changes in the export structure ($\bar{\mathbf{e}}$) is the second most important factor impacting the VS share changes. They have increased China's VS share with 2.3% from 2002 to 2007, but decreased it with 3.0% from 2007 to 2012 (see Table 3). At first glance, this result seems somewhat counterintuitive because the share of processing exports in total exports, which depend much more on imports than nonprocessing exports, had undergone a considerable decline in both periods. One would therefore have expected that changes in $\bar{\mathbf{e}}$ have decreased the VS share. But, this is not what happened in the period 2002–2007. A logical consequence is that in this period import-intensive products must have gained additional weight in the bundle of exports. To test this, we further decompose $\bar{\mathbf{e}}$ into the trade mode ($\mathbf{w}$) and the commodity composition of the exports ($\mathbf{q}$). The trade mode indicates the share of processing exports in the total exports of each good, while the commodity composition gives the share of the exports of a good (no matter whether processing exports or nonprocessing exports) in national aggregate exports. Then the SDA further allows us to distinguish the VS share changes due to the changes in trade mode from those due to the changes in the export commodity composition (see Appendix D (supplementary material) for analytical details). Table 4 provides the results.

As anticipated, the change in trade mode (i.e. decline in the share of processing exports) decreased the VS share in both periods. This result is overpowered, however, by the effect

Table 4. Contributions of changes in trade mode and in commodity composition to the change in VS share (unit: %).

	2002–2007	2007–2012
Trade mode	−2.6	−1.0
Commodity composition	4.9	−2.0
Total	2.3	−3.0

Table 5. The export shares of the top 10 export industries (as % of total exports).

	2002		2007		2012	
Industry ID	P	NE	P	NE	P	NE
Computers and other electronic equipment	13.8	2.3	20.9	2.8	18.9	2.9
Electric equipment and machinery	4.4	2.2	4.2	3.0	4.0	3.8
Instruments, meters, cultural and office machinery	4.4	0.4	3.2	0.7	0.7	0.6
Wearing apparel, leather, furs, and related products	4.2	4.8	2.0	4.2	1.8	6.1
Chemicals	2.8	4.2	2.7	4.7	2.3	5.2
Textile goods	2.5	6.3	1.4	6.9	0.6	3.3
Common and special equipment	1.6	2.6	1.9	3.9	2.9	4.9
Metal products	1.6	1.9	1.2	2.4	0.8	2.4
Transport equipment	1.1	1.1	1.4	1.9	2.3	2.3
Paper, printing and record medium reproduction	2.3	0.9	1.6	1.0	3.3	1.0
Labor-intensive industries (6–10)	8.4	14.4	4.6	14.2	3.2	13.3
Equipment and machinery (16–20)	25.2	8.6	31.6	12.2	28.9	14.2
Service (27–40)	–	21.2	–	13.0	–	17.8
All industries	48.1	51.9	45.7	54.3	39.5	60.5

Note: P = processing exports; NE = nonprocessing exports. Here, the labor-intensive industries includes *Manufacturing of food products and tobacco processing, Textile goods, Wearing apparel, leather, furs, and related products, Sawmills and furniture*; The equipment and machinery includes *Common and special equipment, Transport equipment, Electric equipment and machinery, Computers and other electronic equipment, Instruments, meters, cultural and office machinery*.

of the changes in the commodity composition of the exports, which has substantially increased the VS share from 2002 to 2007 and decreased the VS share from 2007 to 2012. Therefore, the export structure changes have increased VS share from 2002 to 2007 instead of reducing it.

To provide more detailed insight into the changes, Table 5 gives the export shares, distinguishing between processing and nonprocessing exports, for the 10 largest exporting industries in China in 2002, 2007, and 2012. For example, the processing exports of *Computers and other electronic equipment* constituted 13.8% of all Chinese exports in 2002. A shift of exports from labor-intensive industries (industries 6–10) and services to capital-intensive industries is observed from 2002 to 2007. More specifically, the export share of *Equipment and machinery* (industries 16–20) has increased from 33.8% to 43.8% from 2002 to 2007. Since the labor-intensive industries and services usually have much lower VS shares than the capital-intensive industries (Yang et al., 2015), changes in the commodity composition eventually increased the import dependence of China's exports from 2002 to 2007. Differently, in the period 2007 to 2012, China's export share of services has substantially increased from 13.0% to 17.8%, which has decreased the VS share. All of these changes indicate an improvement of China's export commodity composition to products with a higher value-added ratio and more advanced technology.

Table 6. The decomposition of China's VS share on constant price IO tables (unit: %).

	2002–2007				2007–2012			
	D	P	N	Sum	D	P	N	Sum
A^K	0.3	0.3	1.0	1.6	0.1	−0.7	−0.5	−1.1
c	1.0	−0.9	−1.3	−1.3	0.0	0.2	0.7	0.9
R	0.7	−4.5	−3.1	−7.0	0.9	−1.1	−4.0	−4.2
S	0.3	−0.6	0.2	−0.1	0.2	0.1	0.1	0.4
ē	0.0	1.8	0.8	2.6	0.0	−0.6	−2.4	−3.0
Sum	2.3	−3.9	−2.5	−4.1	1.2	−2.1	−6.1	−7.0

Notes: D = production by DEs for domestic use only; P = production of processing exports; N = production of nonprocessing exports and production of FIEs to meet domestic demand; DEs = domestic enterprises; FIEs = foreign-invested enterprises.

5.4. A robustness check

In the analysis above, we have decomposed the changes in the VS share using the tripartite tables in current prices. However, when making intertemporal comparisons, it is customary to deflate IO tables and compare transactions in constant prices. In this subsection, we check the robustness of our decomposition results. We first transform the 2007 and 2012 Chinese tripartite tables into tables in 2002 prices and then redo the entire analysis. To estimate the IO tables in constant prices, we follow the research of Pei et al. (2012) and use the so-called double-deflation method.[20] Applying the same decomposition procedure as before for the tripartite tables in current prices yields results for the constant priced tripartite tables listed in Table 6. It appears that the results are consistent with those in Table 3 with slight differences in the magnitudes.

6. Conclusion

This paper presented the annual estimates for China's VS share from 2000 to 2012 using the tripartite input–output (IO) tables. We found that China's VS share changed its upward trend and declined steadily since 2005, implying a decreased dependence of China's exports production on imports. To explore what might have caused such a decline of the VS share, we developed a new structural decomposition to quantify the contribution of the main factors to the overall change in China's VS share. The decomposition allowed us to capture the contribution of different production types as well as the substitution among different inputs to the VS share change. We eventually decomposed the changes in China's VS share between 2002 and 2007 and between 2007 and 2012 into the effects of 14 components.

  We found that the substitution of imported intermediates with domestically produced intermediates was the main driver for China's declining VS share. This substitution effect was observed for the production of processing exports and for the production of non-processing exports and the production of FIEs to meet domestic demand. The findings suggest an upgrade of China's role in the GVCs instead of moving the 'world's factory'

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[20] WIOD provides detailed price information at the industry level for 40 countries including China. However, it only covers the period from 1995 to 2009 and the industry classification is very different from that in the tripartite tables. Instead, the output price from the NBS was used for the deflation. In details, price index for the agricultural sector is proxied by the producer price index (PPI) of agricultural products. The ex-factory price indexes from NBS for secondary industries are adopted to match the IO sector classification. Price index for construction is proxied by the price index of fixed capital investments. Similarly, the consumer price index of different categories is used to proxy the price index for the tertiary industries (all data are from NBS).

out of China, as suggested by the declining shares of processing exports in total exports. The results imply that improving the quality and competitiveness of domestic intermediates may be an efficient way to upgrade a country's role in the GVCs. To this end, more research and development inputs and FDI inflows to high-technology industries should be further encouraged.

Another interesting finding that has initially caused some surprise is that the changes in exports have increased China's VS share in the period 2002 to 2007 but decreased it from 2007 to 2012. The share of processing exports, which is highly dependent on imports, has declined continuously since 2005. One would therefore have expected that the changes in the shares of processing exports in total exports would have decreased the VS share in both periods. The increase in the first period (2002 to 2007) was due to changes in the commodity composition of the exports. In the period 2002–2007, China changed to exporting more capital-intensive products, which depend more on imported intermediates. This indicates that also adjusting the commodity composition of the exports may be effective to move up the GVCs.

China's path is of interest to other developing countries (such as South Asian and Sub-Saharan African countries) that seek to increase their involvement in GVCs or achieve a higher position in the GVCs. China's development has been to first participate in GVCs by carrying out simple assembly and processing tasks (processing trade). The second step has been to actively move up the GVCs by (i) increasing the domestic inputs in the production of exports, and (ii) adjusting the export commodity composition. This followed from learning-by-doing and the spillover effects of FDI inflows.

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References

Amador, J. and S. Cabral (2009) Vertical Specialisation Across the World: A Relative Measure. *The North American Journal of Economics and Finance*, 20, 267–280.
Bems, R., R.C. Johnson and K-M. Yi (2011) Vertical Linkages and the Collapse of Global Trade. *American Economic Review: Papers and Proceedings*, 101, 308–312.
Chen, H.Y. and Y.M. Chang (2006) Trade Verticality and Structural Change in Industries: The Cases of Taiwan and South Korea. *Open Economies Review*, 17, 321–340.

Chen, X., L.K. Cheng, K.C. Fung, L.J. Lau, Y.W. Sung, K. Zhu, C. Yang, J. Pei and Y. Duan (2012) Domestic Value Added and Employment Generated by Chinese Exports: A Quantitative Estimation. *China Economic Review*, 23, 850–864.

Chen, H., M. Kondratowicz and K-M. Yi (2005) Vertical Specialisation and Three Facts About U.S. International Trade. *North American Journal of Economics and Finance*, 16, 35–59.

Dean, J.M., K.C. Fung and Z. Wang (2011) Measuring Vertical Specialisation: The Case of China. *Review of International Economics*, 19, 609–625.

Dietzenbacher, E. and B. Los (1998) Structural Decomposition Techniques: Sense and Sensitivity. *Economic Systems Research*, 10, 307–324.

Dietzenbacher, E. and B. Los (2000) Structural Decomposition Analyses with Dependent Determinants. *Economic Systems Research*, 12, 497–514.

Dietzenbacher, E., B. Los, R. Stehrer, M. Timmer and G. de Vries (2013) The Construction of World Input–Output Tables in the WIOD Project. *Economic Systems Research*, 25, 71–98.

Duan, Y., C. Yang, K. Zhu and X. Chen (2012) Does the Domestic Value-added Induced by China's Exports Really Belong to China? *China & World Economy*, 20, 83–102.

Feenstra, R.C. and G.H. Hanson (1996) Globalization Outsourcing and Wage Inequality. *American Economic Review*, 86, 240–245.

Feenstra, R.C. and G.H. Hanson (1999) The Impact of Outsourcing and High-technology Capital on Wages: Estimates for the United States, 1979–1990. *Quarterly Journal of Economics*, 114, 907–940.

Helg, R. and L. Tajoli (2005) Patterns of International Fragmentation of Production and the Relative Demand for Labor. *North American Journal of Economics and Finance*, 16, 233–254.

HKTDC (Hong Kong Trade Development Council) (2007) Implications of Mainland Processing Trade Policy on Hong Kong (Research Report, Hong Kong Trade Development Council).

Hummels, D., J. Ishii and K-M. Yi (2001) The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics*, 54, 75–96.

Hwang, S.H., J. Song and S.E. Kim (2011) Vertical Specialisation and Trade Growth in Northeast Asia. *China & World Economy*, 19, 109–126.

Jiang, X., D. Guan, J. Zhang, K. Zhu and C. Green (2015a) Firm Ownership, China's Export Related Emissions, and the Responsibility Issue. *Energy Economics*, 51, 466–474.

Jiang, X., K. Zhu and S. Wang (2015b) The Potential for Reducing China's Carbon Dioxide Emissions: Role of Foreign-Invested Enterprises. *Global Environmental Change*, 35, 22–30.

Johnson, R.C. (2014) Five Facts About Value-added Exports and Implications for Macroeconomics and Trade Research. *Journal of Economic Perspectives*, 28, 119–142.

Johnson, R.C. and G. Noguera (2016) A Portrait of Trade in Value Added over Four Decades (NBER Working Paper No. w22974).

Kee, H.L. and H. Tang (2016) Domestic Value Added in Exports: Theory and Firm Evidence From China. *American Economic Review*, 106, 1402–1436.

Koopman R., Z. Wang and S. Wei (2012) Estimating Domestic Content in Exports When Processing Trade is Pervasive. *Journal of Development Economics*, 99, 178–189.

Koopman R., Z. Wang, and S. Wei (2014) Tracing Value-added and Double Counting in Gross Exports. *American Economic Review*, 104, 459–494.

Lau, L.J., X. Chen, C. Yang, L.K. Cheng, K.C. Fung, Y.W. Sung, K. Zhu, J. Pei, and Z. Tang (2010) Input-occupancy-output Models of the Non-competitive Type and Its Application: An Examination of the China-U.S. Trade Surplus. *Social Sciences in China*, 1, 35–54.

Lawrence, R. (1994) Trade, Multinationals, and Labor (NBER Working Paper No. 4836).

Li, H., Y. Liang, B.M. Fraumeni, Z. Liu and X. Wang (2013). Human Capital in China, 1985–2008. *Review of Income & Wealth*, 59, 212–234.

Liu, Z. (2008) Foreign Direct Investment and Technology Spillovers: Theory and Evidence. *Journal of Development Economics*, 85, 176–193.

Los, B., M. Timmer and G. de Vries (2015) How Global are Global Value Chains? A New Approach to Measure International Fragmentation. *Journal of Regional Science*, 55, 66–92.

Ma, H., Z. Wang and K. Zhu (2015) Domestic Content in China's Exports and Its Distribution by Firm Ownership. *Journal of Comparative Economics*, 43, 3–18.

Mayneris, F., S. Poncet and T. Zhang (2014) The Cleansing Effect of Minimum Wages: Minimum Wages, Firm Dynamics and Aggregate Productivity in China (CORE Discussion Papers 2014044, Université catholique de Louvain, Center for Operations Research and Econometrics (CORE)).

Mundell, R.A. (1957) International Trade and Factor Mobility. *American Economic Review*, 47, 321–335.

Pei, J., J. Oosterhaven and E. Dietzenbacher (2012) How Much Do Exports Contribute to China's Income Growth? *Economic Systems Research*, 24, 275–297.

Ping, X. (2005) Vertical Specialisation, Intra-industry Trade and Sino-U.S. Trade Relationship (Working paper C2005005, China Center for Economic Research, Peking University).

Pugel, T. (2012) *International Economics*. 15th ed. New York, McGraw-Hill.

Slaughter, M.J. (1995) Multinational Corporations, Outsourcing, and American Wage Divergence (NBER Working Paper 5253).

Sun, J.W. (1998) Changes in Energy Consumption and Energy Intensity: A Complete Decomposition Model. *Energy Economics*, 20, 85–100.

Sun, J.W. and B.W. Ang (2000) Some Properties of an Exact Energy Decomposition Model. *Energy*, 25, 1177–1188.

Swenson, D.L. (2005) Overseas Assembly and Country Sourcing Choices. *Journal of International Economics*, 66, 107–130.

Wang, F. (2014). Complementarities Between R&D Investment and Exporting–evidence from China. *China Economic Review*, 31, 217–227.

Yang, C., E. Dietzenbacher, J. Pei, X. Chen, K. Zhu and Z. Tang (2015) Processing Trade Biases the Measurement of Vertical Specialization in China. *Economic Systems Research*, 27, 60–76.

Yeats, A.J. (1998) Just How Big Is Global Production Sharing? Manuscript, World Bank.

Yi, K. (2003) Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy*, 111, 52–102.

Zhang, K.H. (2014). How Does Foreign Direct Investment Affect Industrial Competitiveness? Evidence from China. *China Economic Review*, 30, 530–539.