Impact of Embeddedness in Global Value Chains on the Differentiation of Technological Sophistication of Exports

Siyu Wang, Lekai Zheng*

This paper adopts the production decomposition developed by Wang *et al*. (2017) and data from the World Input-Output Database (WIOD) to estimate the degrees of forward and backward participation in global value chains (GVCs) in 2000–2014 by the world's major economies including China, and to do an empirical examination on the impact that heterogeneous forms of participation in GVCs have on the improvement of GVCs. The results show that forward participation in GVCs helps increase the sophistication of exports, while backward participation in GVCs exerts different influence on the sophistication of exports. While a lower level of backward participation by a country is constrained by the country's current position in the international division of labor and thus does not help increase the sophistication of its exports, a higher level of backward participation helps break through the bottleneck of low-end locking in GVCs and increase the sophistication of exports.

Keywords: global value chain (GVC), technological sophistication of exports, production decomposition model

1. Introduction

A division of labor system along global value chains (GVCs), led by American and European multinational corporations, is increasingly mature and complete against the backdrop of vertical specialization of global production. This system is widely recognized to be conducive to global trade and economic development. As the division of labor deepens along GVCs, some countries upgraded their industrial structure and moved up in the in the GVC network by seizing opportunities in the process of global industrial restructuring. For developing countries, one the one hand, participation in the division of labor promotes employment and increases economic profits in the short term. On the other hand, the technological spillover and learning effect that occur in this process can push up the quality and technological level of their exports, and these countries can

* Siyu Wang (email: mayjay435@163.com), Lecturer, School of Trade Negotiations, of Shanghai University of International Business and Economics; Lekai Zheng (email: lekaizheng@aliyun.com), Postdoctoral researcher at School of Management of Fudan University and Shanghai Gold Exchange.
This work was supported by the 2019 Discipline Building Program of the Shanghai University of International Business and Economics, the WTO Workshop Programme and the Shanghai Center for Global Trade and Economic Governance.

move to a more advantageous position in the international division of labor and gain a chance to move their industries up the GVCs. The Four Asian Tigers in the 1960s, for example, actively participated in the division of labor along GVCs by launching export-oriented policies and “triangle manufacturing strategies;” in the meantime, they basically completed the transformation from processing and assembly to original equipment manufacturing, and to original brand manufacturing, and achieved economic take-off in a relatively short period of time. While enjoying the benefit of globalization, however, it should be noted that some developing countries, though also involved in international cooperation and division of labor, have seen their positions in value chains “solidified” and “locked” at the low ends of value chains, finding it extremely hard to pursue industrial transformation and upgrading. Lall *et al*. (2005) observed that South Asian countries such as Sri Lanka and Pakistan, due to their specific local conditions, relied so heavily on textile exports that they are locked at the labor-intensive low ends of value chains. Therefore, the division of labor along GVCs can be a double edged sword.

Since its reform and opening up, China, with advantageous low costs for such factors of production as labor and land, has participated in the production activities along GVCs through processing trade, resulting in rapid growth in its foreign trade alongside a constantly improved export structure and a leap in its position in the international division of labor. On the whole, however, most Chinese industries participating in GVCs are still low-value-added, low-tech, labor-intensive ones, and China’s industrial sector, in its entirety, remains at the low end of GVCs. Though processing trade allows China, especially its manufacturing sector, to increase its degree of internationalization, Chinese enterprises involved in the international division of labor can only acquire a limited amount of processing and assembly charges, which means low actual gains from trade (Gao *et al*., 2015). On the one hand, with labor costs surging and demographic dividend disappearing in China, the past extensive development model featuring low labor costs will obviously not last, and exports will suffer from the ceiling effect. On the other hand, more developing countries are actively participating in the division of labor along GVCs, adding to the intensity of competition. These, coupled with rising protectionism against globalization since the 2008 financial crisis, are exerting grave impact on the transformation and upgrading of the real economy of China. Therefore, given the above-mentioned unfavorable economic constraints, how China is embedded in GVCs will have a far-reaching influence on the improvement of its position in GVCs.

Previous studies on GVCs are mostly case studies focusing on particular products. Among classic case studies are those on iPhone and Barbie production models. But a case study can only examine the international division of labor for a particular product or industry chain and its gains from trade, containing no analysis at the industry or country level. Global input-output databases have helped us extend the focus of GVC studies from microeconomic to macroeconomic aspects. Hummels *et al*. (2001) was the first to point out that a country may participate in international division of labor in two ways. One, known as backward participation, is represented by the percentage of intermediate inputs that a country imports to produce goods to be exported, i.e. the share of vertical specialization share (VSS); while the other is forward participation in GVCs (known as VS1), denoting the share of the value of a country's exports that are contained in a second country's exports. However, due to data structure limitations, a single country's input-output tables cannot reflect the diffusion and feedback effects caused by the import and export of intermediate goods, as well as information of the international division of labor, as global input-output tables do (Miller and Blaire, 2009). Global input-output tables offer detailed input and output data at country-industry level and detailed information on destinations of inputs and outputs, making it easy to track the uses of factors. Both Wang *et al*. (2013) and Koopman *et al*. (2014) estimated, from the perspective of backward linkage, a country's exports in its trade value-added at country-industry level, and proposed methods for trade value-added decomposition known as WWZ and KWW, respectively, which have become main methods for GVCs evaluation and research. Wang *et al*. (2007) noted, however, that in the practical context today, as regional value chains inside a country and GVCs running simultaneously, links of economic production are increasingly close, so the degree to which a country participates in GVCs should be determined by the production activities of its entire economy. Therefore, the production decomposition model, as a refined version of the trade value-added decomposition model, can depict GVCs more systematically and more accurately; they also creatively built an indicator system for the identification of ways and degrees of participation in GVCs, and used it to evaluate the positions of countries and industries therein in the division of labor systems along GVCs.

It is not hard to find from the above description that most studies in this area focus solely on how GVC embeddedness affects a country's or an industry's technological sophistication and structure of exports and subsequently the paths to improve value chains, without conducting in-depth analysis on whether the heterogeneity among ways of value chain participation has any influence on the technological sophistication of exports. While participation in GVCs allows a country and its enterprises to build their international competitiveness and better cope with growing external competition through homegrown innovation and multiple other ways, there are diverse ways of participating in GVCs, including not only undertaking jobs in such high value-added links as R&D and design, production and supply of key parts and components, and brand innovation, but getting involved in the international division of labor by means of low-tech processing and assembly, original design/equipment manufacturing, etc. The two types of participation in GVCs, though they may have an identical value of embeddedness, obviously differ in the corresponding status and position in GVCs. In light of the above analysis, this paper will, based on the production decomposition model developed by Wang *et al*. (2017) and with the aid of World Input-Output Database (WIOD), give an in-depth analysis of the different effects that the heterogeneity among ways of participation in GVCs has on the technological sophistication of exports. This study is of great value to how China's manufacturing industry is climbing to the middle and high end of value chains.

2. Theoretical and Mechanism Analysis

2.1. GVC Embeddedness Increases Technological Sophistication of Exports

First of all, GVC embeddedness helps increase the technological sophistication of exports through cost effects. Involvement in the international division of labor along GVCs lowers transaction costs. On the one hand, participating in the international division of labor along GVCs furthers the process of trade liberalization and investment facilitation. Athukorala *et al*. (2011) holds that the division of labor along GVCs has increased the reliance that the three global production networks, i.e. West Europe, East Asia, and North America, have on one another, that countries and regions involved in vertical specialization are more likely to enter GVC-based regional trade agreements (RTAs) or bilateral investment treaties (BITs), have made major breakthroughs in promoting trade facilitation and market access, and will continue to advance trade liberalization. Orefice and Rocha (2014) also agree that member states of an economic alliance, when a production network has been established among them, are also willing to sign trade agreements of higher levels. Meanwhile, with management costs for search, supervision and overseas activity outsourcing lowered, gains from specialization are acquired in brand-new ways, a model that has changed the previous factor endowment-based analysis framework of the enterprise boundary theory. That a company headquartered in a technologically advanced country imports intermediate inputs from a less advanced country embodies lower transaction costs, lower wages for low-skilled workers, and lower corporate income tax than purchasing the same in the company's home country.

Secondly, GVC embeddedness helps increase the technological sophistication of exports through the division of labor effects. One of the fundamental reasons for the establishment of GVCs is that the division of labor extends beyond traditional boundaries of countries and into the whole world to broaden the scope of comparative advantage, and enterprises involved in the international division of labor tend to outsource jobs for which they have no advantage over other enterprises, to acquire efficient and specialized factors of production, so that they can focus on production activities within their core links, bring into full play their comparative advantages, and allocate internal resources efficiently. Meanwhile, participating in the international division of labor not only enhances collaboration and communication within enterprises but strengthens production relations between them, leading to the economies of scale in all aspects of production, improved labor productivity and industrial technology, lowered production costs and increased productive efficiency, and ultimately heightened international competitiveness. Moreover, with the increasing tradability of modern finance, computer information, business and other advanced and specialized producer services, there is a remarkable growing trend in the servitization of manufacturing, with a magnitude of premium service factors embedded as flywheel-like intermediate inputs for production in manufacturing to improve the productivity of manufacturers.

Finally, GVC embeddedness helps increase the technological sophistication of exports through technology spillover and transfer effects. Enterprises in the upstream of global production networks are willing to transfer to those in the downstream of the networks knowledge needed to ensure the quality of products and smooth production thereof, so that the latter can possess technological and management expertise to produce related intermediate goods or parts and components, thus improving the level of technology in all parts of the value chain to meet the needs of product upgrading. Higher technological content in what is purchased and longer local chain of related industries indicate a more remarkable technology spillover effect on the less developed country. Participation in GVCs is also a means of technology diffusion. After analyzing Chinese ICT companies' involvement in the division of labor in respect of vertical specialization, Amighini (2005) concluded that China started from low-end processing and assembly, benefited from technology diffusion and consequently became able to produce high-tech intermediate goods independently, which helped with industrial upgrading. Participation in the division of labor and trade systems in respect of vertical specialization determines that intermediate goods exist inside multinational manufacturers or companies and results in embodied technology spillovers. The spillover of advanced technologies and innovations, in turn, promotes technological advancement.

2.2. GVC Embeddedness May Inhibit Technological Sophistication of Exports

GVC embeddedness may inhibit increase in the technological sophistication of exports through the technology lock-in effect. Enterprises in the upstream of GVCs led by developed European and American countries and multinational companies therein, especially in captive and hierarchical GVCs, have absolute dominance. They try to embody technology and knowledge in production equipment to make it hard to learn them, and in international cooperation, they pay close attention to the introduction and application of knowledge and technology. These tend to indirectly increase the costs of technology spillover and tighten the control over access to new knowledge. Thus, there is a lack of knowledge transfer in key areas of innovation and the recipient enterprises in the downstream are forced to give up learning key technologies and only import them as well as corresponding equipment, having no opportunity to obtain advanced technologies. Therefore, enterprises in the upstream block the path to technological innovation for downstream countries and enterprises so that the latter will remain highly dependent on the former, inhibiting the latter's innovation and R&D activities, locking them in low-level processing and assembly and weakening their initiative for upgrading and development (Lu and Hu, 2008). Obviously, that is not good for the downstream enterprises and countries in terms of technological innovation and upgrading, for they are locked at the low end of value chains, and consequently, even if involved in GVCs, they are unable to benefit from it. Moreover, they may even find it hard to enhance productivity and pursue technological progress and impossible to climb up to the middle and high end of GVCs.

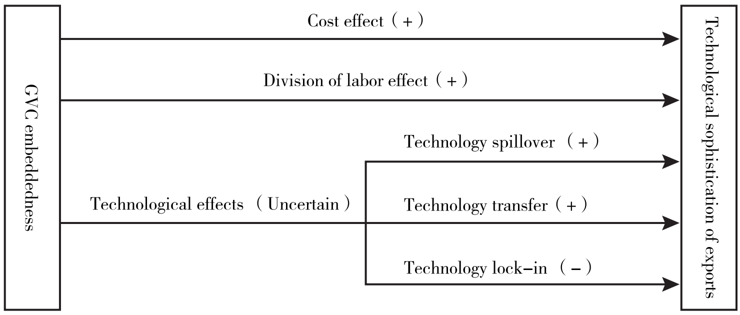

Figure 1. How GVC Embeddedness Impacts the Technological Complexity of Exports

According to the theory of upgrading in value chains, enterprises involved in value chains may raise their positions by following four different paths: processing upgrading, product upgrading, functional upgrading, and chain or sectoral upgrading. When an enterprise, by improving its production processes, adjusting its industrial structure among other activities, moves up a value chain, it will gradually acquire maneuvering room in the value chain framework system and earn more profits therefrom. This is a form of forward participation in a value chain, which obviously helps improve the position in the value chain. Meanwhile, some countries and enterprises, though in the initial stage of their involvement in value chains as low-tech processors and assemblers engaged in low value-added, low-tech and highly energy-intensive assembly segments of the value chains, obviously at low positions in production chains, improve their technological levels through the effects shown in the above figure, namely cost effect, division of labor effect and technology spillover, and extend the value chains at the two ends of the smiling curve and enter more value chains, receiving positive feedback from learning by doing different activities and gradually seeking double embeddedness in the value chain of products and functions. They manage to break free from shackles that locked them at the low end and moved gradually to take part in the manufacturing of sophisticated medium and high-end products, ultimately achieving industrial upgrading and raising their positions in the value chains. Some other countries and enterprises see remarkable progress in industrial upgrading in the initial stage of their involvement in GVCs, but as vertical specialization progressed, they may have been locked by developed European and American countries at the low ends of GVCs, performing simple and low value-added production activities for long with industrial upgrading hampered and the path up in the value chains blocked; their positions on value chains, therefore, see no significant improvement, that is, they are locked in low value-added, low-tech manufacturing segments. The reason for such a phenomenon is that those countries or enterprises rely heavily on GVC organizers and leaders. In comparison, multinational companies use their technological innovation power, brand advantages, and monopoly over global marketing channels to keep tight control over the distribution of trade profits along GVCs and economically oppress countries and enterprises in the downstream of the value chains. It is thus observed from the above analysis that the impact of participation in GVCs on the technological sophistication of exports is in fact a double-edged sword. That is to say, GVC embeddedness impacts the technological sophistication of exports through the cost effect, the division of labor effect and other effects, as illustrated in Figure1.

Therefore, we assume that GVC embeddedness may promote or inhibit the improvement of the technological sophistication of exports and the move up the value chains. The difference may be associated with the ways of participation in GVCs, while the degree of GVC embeddedness may also have heterogeneous impacts on the technological sophistication of exports.

3. Research Method and Cross-Border Comparison

3.1. Introduction to the Production Decomposition Model

We will build a simple cross-border input-output model for N sectors of Country G to explain the production decomposition model (see Table 1), where Z is an intermediate matrix that comprises all relations between upstream industries and downstream industries in the production activities of a country, and Y and X stand for the final demand and the total output matrix, respectively. The relationship between the three is: $X=Z+Y=AX+Y=BY$, where the input coefficient matrix $A=Z\hat{X}^{-1}$ and the Leontief inverse matrix $B=(I-A)^{-1}$.

To make things easier, we take national production activities in Country S as an example to explain the model. A country's production activities may roughly be divided into production activities to meet domestic demand and foreign demandr respectively. According to purposes, production activities can further fall into those to meet intermediate demand and those to meet final demand. Therefore, Country S' uses of outputs can be expressed as

$$X^s = A^{ss}X^s + \sum_{r\neq s}^{G} A^{sr}X^r + Y^{ss} + \sum_{r\neq s}^{G} Y^{sr} \tag{1}$$

where A^{SS} and A^{SR} are Country S' internal input matrix and its input matrix in relation to Country R. Formula (1) can be transformed into:

$$X^s = (I - A^{ss})^{-1}Y^{ss} + (I - A^{ss})^{-1}E = B^{ss}(Y^{ss} + E) \tag{2}$$

where E stands for exports and $B^{SS}=(I-A^{SS})^{-1}$. The production decomposition model allows forward decomposition or backward decomposition, depending on what perspective to take. Forward decomposition is based on the specific destinations of country-sector value added, and backward decomposition on the sources of country-sector output value. Below is the form of forward decomposition of production activity obtain by using the method developed by Wang *et al*. (2017):

$$
\begin{aligned}
(V^s)' &= \hat{V}^s X^s = \underbrace{\hat{V}^s L^{ss} Y^{ss}}_{(\mathrm{I})\text{-}V\_D} + \underbrace{\hat{V}^s L^{ss} \sum_{r\neq s}^{G} Y^{sr}}_{(\mathrm{II})\text{-}V\_Fin} + \underbrace{\hat{V}^s L^{ss} \sum_{r\neq s}^{G} A^{sr} \sum_{u}^{G} B^{ru} \sum_{\mathrm{t}}^{G} Y^{ut}}_{(\mathrm{III})\text{-}V\_Int} = \underbrace{\hat{V}^s L^{ss} Y^{ss}}_{(\mathrm{I})\text{-}V\_D} \\
&+ \underbrace{\hat{V}^s L^{ss} \sum_{r\neq s}^{G} Y^{sr}}_{(\mathrm{II})\text{-}V\_Fin} + \underbrace{\hat{V}^s L^{ss} \sum_{r\neq s}^{G} A^{sr} L^{rr} Y^{rr}}_{(\mathrm{III}a)\text{-}V\_Int\_R} + \underbrace{\hat{V}^s L^{ss} \sum_{r\neq s}^{G} A^{sr} \sum_{u}^{G} B^{ru} Y^{us}}_{(\mathrm{III}b)\text{-}V\_Int\_D} \\
&+ \underbrace{\hat{V}^s L^{ss} \sum_{r\neq s}^{G} A^{sr} \left(\textstyle\sum_{u}^{G} B^{ru} \sum_{t\neq s}^{G} Y^{ut} - L^{rr} Y^{rr}\right)}_{(\mathrm{III}c)\text{-}V\_Int\_F}
\end{aligned}
\tag{3}
$$

Table 1. Input-Output Model for *N* Sectors of Country (or Region) *G*

Input \ Output		Intermediate use 1	2	⋯	G	Final use 1	2	⋯	G	Total output
Intermediate input	1	Z^{11}	Z^{12}	⋯	Z^{1g}	Y^{11}	Y^{12}	⋯	Y^{1g}	X^1
	2	Z^{21}	Z^{22}	⋯	Z^{2g}	Y^{21}	Y^{22}	⋯	Y^{2g}	X^2
	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋱	⋮	⋮
	G	Z^{g1}	Z^{g2}	⋯	Z^{gg}	Y^{g1}	Y^{g2}	⋯	Y^{gg}	X^g
Value-added		V^1	V^2	⋯	V^g					
Total input		$(X^1)'$	$(X^2)'$	⋯	$(X^g)'$					

As shown in Formula (3), forward production decomposition may further be broken down into three parts: value added that meets only domestic final demand (D), value added that meets the export of final products among exports (Fin), and value added that serves the export of intermediate goods among exports (Int); economic activity for the first two parts involves no cross-border division of labor and cooperation and thus do not belong to the GVC division of labor system, and only the last part belongs to production activity geared to the GVC division of labor. This value added may be divided further into: value added that is directly absorbed by country r (Int_R), value added that is returned to the exporting country s (Int_D), and value added that is indirectly absorbed or exported to a third country by country r (Int_F). Specifically, Int_R means that country r uses intermediate goods imported from the country s to produce final goods to be consumed in country r; Int_D means that the country r uses intermediate goods imported from the country s to produce final goods or other intermediate goods to be exported directly or via other countries in GVCs to country s for the purpose of satisfying final demand in the country s. *Int_F* means that the country r uses intermediate goods imported from country s to produce final goods or other intermediate goods to be exported to the country t for consumption or where final goods are produced and then exported to other countries. Different stages embody different economic meanings and manifest different types of cross-border division of labor in production. While *Int_R* involves cross-border trade in value added only once and reflects a simple form of forward participation in GVCs, both *Int_D* and *Int_F* involve cross-border trade in value at least twice and reflect a relatively complicated form of forward participation in GVCs.

Similar to forward decomposition described above, final goods at country-sector level can also be decomposed backwards based on the input aspects of input-output relations, which will not be explained in detail here. Therefore, from the perspective of forward and backward correlations concerning value added, we can estimate the share of GVC embeddedness, i.e. the forward embeddedness index and the backward embeddedness index:

$$INT\_f = \frac{V\_Int\_R}{\hat{V}X} + \frac{V\_Int\_D}{\hat{V}X} + \frac{V\_Int\_F}{\hat{V}X} \tag{4}$$

$$INT\_b = \frac{Y\_Int\_R}{Y} + \frac{Y\_Int\_D}{Y} + \frac{Y\_Int\_F}{Y} \tag{5}$$

4. Differentiated Impacts of GVC Participation Types on the Technological Complexity of Exports

4.1. Variable Selection, Modeling and Data Sources

4.1.1. Explained Variables and Their Measurements

Regarding the explained variable "technological sophistication of exports", previous studies have adopted the method proposed by Hausmann *et al*. (2007). Due to the overweight of the income level of each country in the model, however, the practical application of the method easily leads to the recurrent conclusion that products with high technological sophistication levels are produced by developed countries, while products with low technological sophistication levels are produced by developing countries (Li, 2015). In view of this, Hausmann and Hidalgo (2010) reckoned that products are made by combining specific subsets of non-tradable productive inputs (which was called capabilities). Countries differ in the number and specific combination of the capabilities they have and products differ in the combination of capabilities they require. Therefore, countries with more capabilities may be able to make more types of products, while the manufacturing of products requiring more capabilities may be accessible to fewer countries. This means that by measuring the number types of products manufactured or exported by a country, we can deduct the number of capabilities owned by the country. Similarly, by measuring the number of countries that produce or export a certain product, we can deduct the number of capabilities required to manufacture the product. In this way, a bipartite network is constructed, constituting country and its exported products, to measure the sophistication of the country and its exports. The method defines the sophistication of an economy through diversification, indicating the number of products with revealed comparative advantage (RCA), and defines the sophistication of a product through ubiquity, indicating the number of countries with RCA in a certain exported product.

In the calculation process of this method, we first need to calculate the RCA index at the product level of each country with the following formula:

$$RCA_{cp} = \frac{E_{cp} \Big/ \sum_{c} E_{cp}}{\sum_{p} E_{cp} \Big/ \sum_{cp} E_{cp}} \tag{6}$$

where E_{cp} represents the export volume of product p by country c and thus, RCA_{cp} indicates whether country c has a significant advantage in the export of product p. When $RCA_{cp}>1$, country c has more comparative advantages in the world trade of product p, indicating higher international competitiveness. Otherwise, the country lacks international competitiveness in the product. On this basis, we can build an association matrix M to describe the connections between the countries and the products in a two-country network:

$$M_{cp} = \begin{cases} 1, \textit{ if } RCA_{cp} > 1 \\ 0, \text{ otherwise} \end{cases} \tag{7}$$

Therefore, the sophistication of the country and the product could be calculated as:

$$k_{c,0} = \sum_{p} M_{cp} \tag{8}$$

$$k_{p,0} = \sum_{c} M_{cp} \tag{9}$$

$$k_{c,n} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} k_{p,n-1} \tag{10}$$

$$k_{p,\mathrm{c}} = \frac{1}{k_{p,0}} \sum_{c} M_{cp} k_{c,n-1} \tag{11}$$

where n represents the number of iterations required, $k_{c,0}$ and $k_{p,0}$ respectively represent the diversification of the country in product and the ubiquity of the product at the country level in the initial situation. By means of iterative operation, the country's technological sophistication of exports and product sophistication could be measured. This method of measuring the sophistication of the country and its exported products has been well recognized and widely used in the academic world (Tacchella *et al*., 2013). As Gabrielli *et al*. (2017) pointed out, despite the theoretical basis from the RCA, the method only factored in the proportion of each exported product's value, while neglecting the degree of the productive inputs for different exported products and the degree of difficulty in export. Albeaik *et al*. (2017) proposed corrections to the export value of each country by correcting the export volume of product *a* by country *c* based on the difficulty in export. It is defined as:

$$X_c^{'a} = \sum_p \frac{X_{cp}}{\sum_c \frac{X_{cp}}{X_c^0}}$$

where X_c^0 represents the export volume of country *c*. Using this definition, we can deduct that the corrected value of export of Product *N* by country *c* as:

$$X_c^{'n} = \sum_p \frac{X_{cp}}{\sum_c \frac{X_{cp}}{X_c^{n-1}}}$$

Based on the corrected product values of each country, we can use Formula (6) to recalculate the export comparative advantage matrix. Then, we can perform the above iterative operations to measure the technological sophistication of the country's exports.

4.1.2. Modeling

Based on the existing literatures on the factors affecting the technological sophistication of exports (Hausmann *et al*., 2010), the following measurement model is constructed:

$$EXPY_{it} = \alpha_0 + \beta GVC_{it} + \gamma Control + \eta_i + \mu_t + \varepsilon_{it}$$

where *i* represents country, *t* represents time, η_i represents country fixation effect, μ_t represents time fixation effect, and *Control* represents other control variables. GVC_{it} represents the degree of GVC participation. For the specific construction method of this indicator, see the third section of this paper. In addition, given the robustness of the measurement results, the following control variables are also taken into account, including population size (*POP*), human capital (*HUM*), institutional quality (*INST*), R&D investment (*RD*), urbanization degree (*URBAN*), and infrastructure (*INF*). Finally, due to the great differences in the horizontal values of different variables, we have done logarithmic processing on the above data and ε_{it} is the error term.

4.1.3. Data Sources

This paper calculates the technological sophistication of exports (2000–2014) of the world's major economies, including China. The trade data is derived from the bilateral trade data provided by CEPII-BACI. The database contains HS92 for classifying goods in a six-digit code system, comprising the trade data of over 5000 products in more than 200 countries and regions. As for the GVC participation index at the national level in this paper, the data is derived from the cross-country input and output data published by WIOD in November 2016. As for the control variables, this paper uses the population size of each country as a proxy variable for the actual market potential. The log of national average years of schooling in the global education database developed by Barro and Lee (2013) is used as a proxy variable for human capital in PWT 9.0. The data for institutional quality is derived from the Rule of Law database. R&D investment is represented by the proportion of R&D investment in a country's GDP. The urbanization rate is measured by the proportion of urban population in a country's total population. Infrastructure is represented by the number of Internet users per 100 people. All the above data come from the development database of the World Bank.

4.2. Empirical Findings and Analysis

4.2.1. Benchmark Regression Results

Table 2 shows the benchmark results obtained by ordinary least squares (OLS) regression in the two-way fixed effect. The study reveals that the impact on the technological sophistication of export varies greatly with the difference in the model and the degree of GVC participation. First, the results in columns (1) to (3) of Table 2 suggest that the degree of forward GVC participation exerts a significant positive impact on the technological sophistication of a country's exports. Moreover, under the premise of controlling other variables and judging from the economic point of view, one unit of increase in the degree of forward participation in labor division of value chains correlates with an increase of 0.571 unit in the technological sophistication of the country's exports. Likewise, a country's value chain activities with a low degree and a high degree of forward participation in the international division of labor would lead to an increase in the technological sophistication level of the exports by 0.951 and 1.107 respectively.

However, the report results in columns (4) to (6) of Table 2 show the empirical results of the impact of backward GVC participation on the technological sophistication of a country's export. The regression results show that under the premise of controlling other variables, one unit increase in the degree of backward participation in labor division in a value chain correlates with an increase of merely 0.081 unit in the technological sophistication of the country's export, which is not quite obvious in mathematical statistics.

Table 2. Benchmark Regression Results

	Impact of forward participation on sophistication			Impact of backward participation on sophistication		
	(1)	(2)	(3)	(4)	(5)	(6)
GVC	0.571***			0.081		
	(4.580)			(0.402)		
Low GVC participation		0.951***			–1.543***	
		(4.786)			(–4.702)	
High GVC participation			1.107***			0.749***
			(3.730)			(3.471)
POP	0.144***	0.139***	0.149***	0.135***	0.157***	0.144***
	(6.050)	(5.847)	(6.139)	(5.552)	(6.499)	(5.980)
HUM	0.141**	0.136**	0.150**	0.152**	0.115*	0.126*
	(2.149)	(2.076)	(2.261)	(2.259)	(1.744)	(1.885)
INST	0.041*	0.0415*	0.041*	0.046*	0.046*	0.038
	(1.730)	(1.779)	(1.721)	(1.900)	(1.949)	(1.621)
RD	0.116***	0.114***	0.123***	0.130***	0.134***	0.119***
	(8.969)	(8.701)	(9.583)	(9.797)	(10.704)	(9.021)
URBAN	0.922***	0.899***	0.925***	0.826***	0.917***	0.961***
	(5.156)	(5.056)	(5.109)	(4.512)	(5.139)	(5.229)
INF	0.161***	0.162***	0.162***	0.166***	0.157***	0.168***
	(8.500)	(8.554)	(8.443)	(8.530)	(8.247)	(8.772)
Constant	–0.550**	–0.514**	–0.567**	–0.457*	–0.279	–0.499**
	(–2.405)	(–2.261)	(–2.451)	(–1.944)	(–1.216)	(–2.168)
Country fixation	Yes	Yes	Yes	Yes	Yes	Yes
Year fixation	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	530	530	530	530	530	530
Adjusted R^2	0.547	0.548	0.540	0.526	0.548	0.538

Notes: Below the estimated coefficients, the numerical coefficients within the brackets are the *t* statistic of the coefficient estimates. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively (the same below).

Moreover, the regression results show that the impact of different degrees of backward participation on the technological sophistication of a country's export varies considerably. The low degree of backward GVC participation, instead of improving the technological sophistication of a country's exported products, plays a negative and inhibiting role. On the contrary, a high degree of backward GVC participation actively boosts the technological sophistication of a country's exports. We believe that this phenomenon is caused by the fact that for any country, the forward participation in the international division of labor means to undertake more high value-added activities in the production chain, such as the supply of upstream raw materials, R&D design, and production & supply of key components. These activities have a significant positive impact on the country's position in the value chain. In case of the backward participation in the international division of labor, the country would play a dominant role in the processing and assembly in the entire GVC system. Such activities involve mostly low-tech, low-value-added, trivial and simple assembly work. The value chain upgrade of these countries is usually squeezed by leading countries and enterprises in the upstream. In the meanwhile, these countries fail to accumulate sufficient input factors required for the upgrading, such as high-end talents and cutting-edge technologies. In addition, the scarce entrepreneurial resources trapped these countries at the low-end links of the value chain, and thus obstructing these countries from going up the ladder of GVC. At the early stage of integration into the GVC system, some countries and enterprises participated in the international labor division system in an "extensive" manner and depended on the system dominated by developed countries in Europe and America. However, through many positive effects in terms of the cost and the division of labor in international cooperation, these countries (enterprises) have improved their own technological level and increased domestic innovation capabilities. Then, they pursued for dual participation in both product and functional architectures, effectively freed from the trap at the low-end GVC, gradually took part in the higher-level processing and assembly work, and finally achieved industrial upgrading and improved their position in the GVC. It can be seen that the mechanism of action has been an important contributor to the varied impacts of the heterogeneity of GVC participation on the technological sophistication of exports.

4.2.2. Endogenous Test

Given the potential endogenous problems with the above study, a reverse causality may arise in the correlation between the type and the degree of the value chain participation and the technological sophistication of a country's exported products. To eliminate potential errors in the estimated results and reach robust and reliable conclusions, the paper draws on the approach of Lv *et al*. (2017). The paper selects the lag phase of the GVC participation degree as an instrumental variable in the model and re-makes regression estimate of the model by means of the 2SLS (two-stage least squares), in a bid to effectively control the potential endogenous problems in the measurement model. On the one hand, the lag of GVC participation degree is highly correlated with the current GVC participation degree, but not obviously relevant to the error term. On the other hand, the lag of GVC participation degree has no direct impact on the current level of the explained variable—technological sophistication of the exports. Therefore, it simultaneously satisfies the requirements on correlation between instrumental variables and endogenous variables and on exogeneity. Firstly, the possibility of endogeneity with the model was ruled out by the Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic reported in Table 3. Secondly, similar to the benchmark regression results in Table 2, under the premise of controlling other variables, the impact of types and degrees of GVC participation on the technological sophistication did not change substantially. It provides further support to the conclusion that the heterogeneity of GVC participation type exerts differentiated impacts on the technological sophistication of exports.[1]

---

[1] Due to space limitations, the model results of the endogenous test and robustness test for this paper are not reported in detail.

Table 3. Instrumental Variable Regression Results

	Impact of forward participation on sophistication			Impact of backward participation on sophistication		
	(1)	(2)	(3)	(4)	(5)	(6)
GVC	0.725*** (4.513)			0.533* (1.905)		
Low GVC participation		1.232*** (4.846)			−1.342*** (−3.171)	
High GVC participation			1.370*** (3.480)			1.146*** (4.148)
Kleibergen-Paak rk LM	95.02	85.23	102.34	271.10	305.64	327.30
Kleibergen-Paak rk Wald F	92.79	83.06	100.11	635.31	878.93	1096..85
Sample size	496	496	496	496	496	496

4.2.3. Robustness Test

In addition, to further test the reliability of regression results, Hausmann and Hidalgo's (2010) algorithm is adopted to re-calculate the technological sophistication index of each country's exports, which is used as an explained variable for regression estimation. Furthermore, based on the WIOD data (2013 Release), the degree of GVC participation under each category is measured and used as the core control variable to rerun the regression test (see Table 4 and Table 5 for results). The comparison of results show that no matter the explained variable is modified or the core explained variable is replaced, the regression results and benchmark regression results are basically consistent with each other. That is to say, the forward GVC participation in international division of labor can improve the technological sophistication of the country's exports, regardless of the degree of participation, and thus strengthen the country's position in the division of labor in value chains. However, the backward GVC participation has notably differentiated impacts on the technological sophistication of the exported products. A low degree of backward participation, constrained by the country's position in the international division of labor, hinders the improvement of technological sophistication of a country's exports. A high degree of backward participation will break through the bottleneck of being trapped at the low end of the value chains, and thus facilitate the improvement of the technological sophistication of the country's exports.

5. Conclusions

In recent years, a new round of scientific revolution and the booming industrial revolutions have continued to deepen and reshape the global value chain. Whether countries and companies can benefit from participation in globalization depends not only on their successful integration into global value chains, but also on the type of participating in the international division of labor in the value chains. Based on the framework to decompose production activities in Wang *et al*. (2017) and the new WIOD database, this paper empirically tests the differentiated impacts of varied types of GVC participation on the technological sophistication of the exported products. The forward participation in the GVC division of labor, no matter at a low or high degree, can improve the technological sophistication of country's exports and elevate the country's position in division of labor in value chains, and thus help the country benefit from the GVC system. However, the backward GVC participation exerts differentiated impacts on the technological sophistication of exports. A low degree of backward value chain participation may be constrained by the country's passive position in the international division of labor, which hinders it from climbing up to the high end of the value chain and negatively affects the technological sophistication of the country's exported products. Only a higher degree of backward value chain participation can help the country break through the bottleneck of being trapped at the low end of value chains, and thus improve the technological sophistication of the country's exports.

Table 4. Robustness Test Regression Results of Re-Measured Technological Complexity of Exports

	Impact of forward participation on sophistication			Impact of backward participation on sophistication		
	(1)	(2)	(3)	(4)	(5)	(6)
GVC	1.654*** (6.113)			0.022 (0.049)		
Low GVC participation		2.435*** (5.600)			–4.347*** (–6.096)	
High GVC participation			3.908*** (6.113)			1.865*** (3.934)
Country fixation	Yes	Yes	Yes	Yes	Yes	Yes
Year fixation	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	530	530	530	530	530	530
Adjusted R^2	0.413	0.406	0.413	0.366	0.413	0.386

Table 5. Robustness Test Regression Results of Re-Measured GVC Participation Degree Based on WIOD Data (2013 Release)

	Impact of forward participation on sophistication			Impact of backward participation on sophistication		
	(1)	(2)	(3)	(4)	(5)	(6)
GVC	0.659*** (4.054)			0.235 (1.383)		
Low GVC participation		0.959*** (4.100)			–1.045*** (–3.479)	
High GVC participation			0.928*** (2.599)			0.900*** (4.256)
Country fixation	Yes	Yes	Yes	Yes	Yes	Yes
Year fixation	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	525	525	525	525	525	525
Adjusted R^2	0.360	0.361	0.347	0.341	0.355	0.363

Since the reform and opening up 40 years ago, China has seen continuous improvement in the depth and breadth of GVC participation and received huge dividends from opening up. At the new stage of new normal of economic growth, the linchpin for China is to make the best use of its participation in the international division of labor to arrive at the high end of the value chains, and thereby shifting the economic growth model from scale expansion to structural optimization and quality improvement. While enjoying the dividends of opening up, we must be keenly aware that the GVC system has a negative influence as well. It's in this context that the following policy recommendations are proposed. Firstly, China should continue to upgrade industries based on improving quality and technological content. As the world's largest developing country, China should continue to follow the guidance of the 13th Five-Year Plan to promote China's transformation from a trader of quantity to a trader of quality. China should strive to improve the quality and technological sophistication of the manufactured and exported products, in a bid to go up from the low end to the high end in the international division of labor in value chains. Secondly, from the perspective of building an open economy, China should continue with all-round opening up. By virtue of the Belt and Road Initiative, China should encourage domestic enterprises and products to go global. Under the premise of safeguarding the country's rights and interests, we should seek mutual benefits and win-win results and keep intensifying China's international right of speech in the making of the international rules. Thirdly, China should accelerate the development of service trade and the servitization in manufacturing. Both product quality improvement and industrial upgrading require the inputs of soft power elements, while the investments in R&D and design are service-oriented products. Therefore, the industrial entities and traditional production lines in China should shift toward service elements and service-oriented manufacturing processes. In this way, the global industrial chain will be lengthened and widened for the Chinese export enterprises and industries to be fully engaged in the global value and industrial chain.

References

Albeaik, S., Kaltenberg, M., & Alsaleh, M. (2017). Improving the Economic Complexity Index. ArXiv Working Paper No. 1707.

Amighini, A. (2005). From Global to Regional Production Networks in the Telecom Sector: Implications for Industrial Upgrading in East Asia. *European Journal of East Asian Studies*, 4(1), 115–142.

Athukorala, P. (2011). Production Networks and Trade Patterns in East Asia: Regionalization or Globalization? *Asian Economic Papers*, 10(1), 65–95.

Barro, J., & Lee, W. (2013). A New Data Set of Educational Attainment in the World. *Journal of Development Economics*, 104, 184–198.

Gabrielli, A., Cristelli, M., & Mazzilli, D. (2017). Why We Like the ECI+ Algorithm. ArXiv Working Paper No. 1708.

Gao, Y. S., Zhen, C. C, & Zheng, L. K. (2015). Research on the Decomposition of Added Value of China's Exports to the EU—From the Perspective of Vertical Specialization. *The Journal of Quantitative & Technical Economics (Shuliang Jingji Jiliang Jingji Yanjiu)*, 9(32), 73–88.

Hausmann, R., Hwang, J., & Rodrik, D. (2007). What You Export Matters. *Journal of Economic Growth*, 12(1), 1–25.

Hausmann, R., & Hidalgo, A. (2010). Country Diversification, Product Ubiquity, and Economic Divergence. Harvard University Working Paper No. 45.

Hummels, D., Ishii, J., & Yi, K. M. (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics*, 54(1), 75–96.

Koopman, R., Wang, Z., & Wei, S. J. (2014). Tracing Value-added and Double Counting in Gross Exports. *American Economic Review*,104(2), 459–494.

Lall, S., Weiss, J., & Zhang, J. K. (2005). Regional and Country Sophistication Performance. Asian Development Bank Institution Discussion Paper No. 23.

Li, X. P., Zhou, J. S., & Wang, S. B. (2015). Improvement of Technical Complexity of Exports and Growth of China's Manufacturing Industry. *The Journal of World Economy (Shijie Jingji)*, 2(38), 31–57.

Lu, F. C., & Hu, P. B. (2008). Game Analysis on Low-Locked Chinese Enterprises in the Global Value Network. *China Industrial Economics (Zhongguo Gongye Jingji)*, 10(247), 23–32.

Lv, Y., Huang, Y. X., & Chen, Y. B. (2017). The Effect of Global Value Chain Embeddedness on Productivity: An Analysis of its Impact and Mechanism. *The Journal of World Economy (Shijie Jingji)*, 7(40), 28–51.

Miller, R. E., & Blair, P. D. (2009). *Input-Output Analysis: Foundations and Extensions*. Cambridge University Press.

Orefice, G., & Rocha, N. (2014). Deep Integration and Production Networks: An Empirical Analysis. *The World Economy*, 37(1), 106–136.

Tacchella, A., Cristelli, M., Caldarelli, G., & Gabrielli, A. (2013). Economic Complexity: Conceptual Grounding of a New Metrics for Global Competitiveness. *Journal of Economic Dynamics and Control*, 37(8),1683–1691.

Wang, Z., Wei, S. J., & Zhu, K. (2013). Quantifying International Production Sharing at the Bilateral and Sector Levels. NBER Working Paper No. 19677.

Wang, Z., Wei, S. J. Yu, X., & Zhu, K. (2017). Measures of Participation in Global Value Chains and Global Business Cycles. NBER Working Paper No. 23222.