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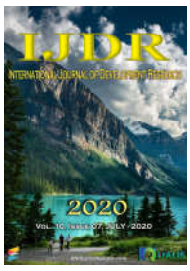

RESEARCH ARTICLE OPEN ACCESS

RESEARCH ON THE RELATIONSHIP BETWEEN GLOBAL VALUE CHAIN AND EXPORT INCOME ELASTICITY—STATISTICAL ANALYSIS BASED ON CHINESE INDUSTRIES

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ABSTRACT

This article reexamines Chinese export trade from a new perspective of the embeddedness of Global Value Chain (GVC) leading to changes in export income elasticity. Based on the export demand model under the incomplete substitution hypothesis, this paper proposes the theoretical hypothesis that the embeddedness of GVC affects the export income elasticity through structural effects and bullwhip additional effect, and empirically tests the above two effects and their impact mechanisms with 2001-2015 import and export panel data of 21 industries. The results show that the embeddedness of GVC will lead to an increase in Chinese export income elasticity. On the one hand, the embeddedness of Chinese GVC is mainly concentrated in the durable goods industry, and the structural elasticity that durable goods export income is greater than that of non-durable goods will increase Chinese export income elasticity. On the other hand, due to the bullwhip effects of GVC supply chain, the embeddedness of GVC has further increased the sensitivity of Chinese exports to foreign income, resulting the increase of export income elasticity, and this effect is even more pronounced during economic fluctuations. Chinese enterprises should pay attention to the changes in export income elasticity while embedding GVC, actively optimize the export structure, improve the international competitiveness of export products, and stabilize export trade.

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INTRODUCTION

Against the background of the slowdown in global economic growth, the anti-globalization of some developed countries, and the ever-changing trade frictions between China and the United States, growth rate of Chinese export has dropped significantly. From 2009 to 2015, the average annual growth rate of Chinese export not only decreased by 6% compared with 1995 to 2008, but also fell faster than the world GDP during the same period. The reason is that in addition to the shrinking foreign demand caused by the global economic downturn, the change in the elasticity of export income will also produce a multiplier effect, which further amplifies this downward trend. Therefore, clarifying the influencing factors of the current changes in export income elasticity will help to more accurately judge Chinese export situation and provide a theoretical basis for relevant departments to formulate policies and measures to "stabilize foreign trade". Existing research mainly focuses on the positive impact of the embeddedness of GVC on exports, and rarely pays attention to the risks brought by it. Even if it studies its risks, it mainly proposes that the low-end embeddedness of GVC is not conducive to export upgrade from the perspective of value added. This paper discusses the risks faced by Chinese industries embedded in GVC from a new perspective of the embeddedness of GVC leading the increase of export income elasticity. Existing literature shows that although there are many factors affecting export income elasticity, they can be roughly divided into two types: changes in exchange rate and changes in external conditions. In terms of exchange rate factors, both the exchange rate level and exchange rate fluctuations will cause changes in export income elasticity. Among them, the exchange rate level is part of the relative price and cannot be ignored in estimating the export income elasticity, otherwise it will cause certain bias (Berman et al. 2012); Due to the time lag of international trade, the uncertainty from exchange rate fluctuations will also affect exports, especially exports of products with higher sunk costs (Li et al., 2015). Among the external conditions, total factor productivity and foreign investment are the most important influencing factors. Generally speaking, industries with high total factor productivity have a larger market share, stronger pricing power and higher cost-plus (Atkeson and Burstein, 2008). When the foreign economy fluctuates, export enterprises reprice by

adjusting the cost-plus, thereby changing the impact of foreign income changes on exports, and then changing the elasticity of export income. The impact of foreign direct investment on exports is very complex, and the substitutional relation and complementary relation will have a completely different impact on export income elasticity (Helpman et al., 2004). On the basis of the above research results, the latest foreign studies have found that embeddedness of Global Value Chain (GVC)is also one of the important factors leading the changes in export income elasticity. Generally, scholars consider engaging in processing trade as embedded in GVC and distinguishing it from general trade. On the one hand, compared to general trade, processing trade is deeply involved in the GVC production process and is more sensitive to foreign economic uncertainty. When the foreign economy fluctuates, the GVC supply chain responds through the inventory adjustment mechanism, and the inventory adjustment range is greater than fluctuations in external demand itself, which leads to higher sensitivity of processing trade to foreign economic fluctuation than general trade (Altomonte et al., 2012). On the other hand, the embeddedness of GVC has obvious industry aggregation in the industry distribution, mainly concentrated in the durable goods industry represented by electromechanical products (Eaton et al., 2016). The different export income elasticity of durable goods and non-durable goods further leads to the heterogeneity of export income elasticity between embedded GVC and non-embedded GVC (Engel and Wang, 2011). In contrast to Chinese reality, great changes have taken place in Chinese export methods with the continuous development of the division model based on GVC. From 1995 to 2015,Chinese total export of processing trade increased from $ 73.7 billion to $ 797.79 billion, and became the most important way for China to integrate into GVC. At the same time, Chinese export income elasticity has also shown significant synchronization with the embeddedness of GVC. From 1992 to 2006, with Chinese continuous integration into the GVC division system, its export income elasticity has increased to 2.34 (Yao Zhizhong et al., 2010).After joining WTO, the embeddedness of Chinese GVC has increased significantly, and its export income elasticity has also shown obvious increase trend. The obvious synchronization of the embeddedness of GVC and export income elasticity reminds us of the need to further consider how the embeddedness of GVC affects export income elasticity.

Throughout the existing literature, the relationship between the embeddedness of GVC and export income elasticity is inconclusive. Scholars represented by Gangnes et al. (2014) believed that the increase in the embeddedness of GVC was the main driving force for the increasing income elasticity of exports in the past few decades. Correspondingly, the export elasticity of processing trade was also significantly higher than that of general trade (Thorbecke and Smith, 2010; Bergin et al., 2012). However, this view was opposed by scholars represented by Johnson and Noguera (2012), who insisted that there is no direct evidence to show that there is a relationship between embedded GVC and export income elasticity, and further pointed out that some scholars misunderstood the correlation between the two is because the traditional accounting method has the problem of recalculating part of the exports, which leads to the "illusion" that the value of export income elasticity increases. It is regrettable that none of the above scholars gave a clear discussion and answer on the mechanism of the embeddedness of GVC affecting export income elasticity. Based on this, this paper intends to expand the existing research from the following two aspects. On the one hand, based on the the consideration of traditional influencing factors such as exchange rate levels, exchange rate fluctuations, total factor productivity, and foreign investment, this paper adds the new influence variable, the embeddedness of GVC to further examine whether the embeddedness of GVC will increase export income elasticity from the industrial view. On the other hand, based on the distinction between processing trade and general trade, this article analyzes the structural characteristics of the embeddedness of GVC in the industry distribution and the heterogeneity of GVC supply chain, determining the impact mechanism of the embeddedness of GVC on export income elasticity, extending the breadth of existing research. On this basis, this article also subdivides the time span of the sample into two periods of economic stability and economic fluctuation, detailing discussing the impact of the embeddedness of GVC on the elasticity of export income in different periods. Based on this, the remaining article structure is arranged as follows. The second part is to construct the analysis framework of the impact of the embeddedness of GVC on export income elasticity and propose related assumptions by analyzing the heterogeneity of export income elasticity between processing trade and general trade. The third part is to conduct a typical factual description of the impact of the embeddedness of GVC on export income elasticity, GVC structure effect and GVC bullwhip effect by using the world input-output data and China Customs data. The fourth part is to conduct empirical test and robustness test on whether the embeddedness of GVC increases export income elasticity by using measurement model based on model design and variable selection. The fifth part further explores the specific impact mechanism of the embeddedness of GVC on export income elasticity. The sixth part draws conclusions and policy recommendations.

Theoretical Framework

In order to examine the impact of the embeddedness of GVC on the elasticity of Chinese export income, this paper uses processing trade (the most important way for the embeddedness of GVC of Chinese enterprises)and general trade as measure mark of whether GVC is embedded by drawing on the practice of Gangnes et al. (2014)and combining the actual situation in China. The former means embedded GVC, the latter means not embedded. By studying the heterogeneity of export income elasticity between the two, the impact of the embeddedness of GVC on export income elasticity is derived. If the export income elasticity of processing trade is greater than general trade, it means that the embeddedness of GVC will increase Chinese overall export income elasticity. At the same time, the core of this paper is to study the source of heterogeneity of export income elasticity in processing trade and general trade, that is, the specific impact mechanism of the embeddedness of GVC on export income elasticity. Therefore, this paper proposes that there are two major impact mechanisms namely structural effect and bullwhip additional effect exist in the embeddedness of GVC.

Structural Effect: China mainly embeds GVC through processing trade, o that the industry distribution characteristics of processing trade directly determine the industry distribution of the embeddedness of GVC. he industrial distribution of processing trade and general trade is asymmetric. The former is mainly concentrated in the durable goods industry, while the export income elasticity of the durable goods and non-durable

goods industries is heterogeneous. These two aspects jointly lead to the difference in the elasticity of export income of processing trade and general trade, then we can get the conclusion that the embeddedness of GVC affects the elasticity of export income, which we call structural effect. Firstly, processing trade is mainly concentrated in the durable goods industry. Compared with general trade, processing trade is a fragmented process of traditional production models, and the production links are resolved vertically along the industrial chain. The production link of the durable goods industry is more in line with this fragmentation process and more segmental. Therefore, Chinese processing trade is mainly concentrated in the durable goods industry. From 2001 to 2015, the proportion of durable goods in Chinese processing trade has remained above 50%, exceeding the proportion of non-durable goods. Secondly, the export income elasticity of the durable goods industry may be greater than that of non-durable goods industries. Compared with non-durable goods, the production of unit durable goods (such as electronic equipment) requires more capital accumulation, and generally belongs to capital intensive industries. Capital intensive industries have more capital requirements, so when external income tightens and capital supply capacity weakens, it will have a greater impact on exports of capital-intensive industries; conversely, the increase in foreign income can increase the availability of capital, thereby increasing the export capacity of capital-intensive industries. This shows that exports of capital-intensive industries are more sensitive to fluctuations in foreign income and are significantly higher than other industries. Because of this resource endowment characteristic of durable goods, when facing the shock of external demand, the export of durable goods changes the most (Alessandria et al., 2009; Bems et al., 2011). Based on this, we infer that the export income elasticity of durable goods industry may greater than non-durable goods industry.

Finally, the export income elasticity of durable goods industry directly determines the export income elasticity of processing trade. Export income elasticity is a measure of the sensitivity of the changes of exports to foreign income, that is, the percentage of changes in exports caused by a 1% change in foreign income in a certain period of time. Assuming that export (X)is divided into two parts: export of durable goods industry (X_1)and export of non-durable goods industry (X_2), and influenced by foreign income (Y),then export income elasticity (E)can be expressed as a function of export income elasticity (E_1)of durable goods industry and export income elasticity (E_2)of non-durable goods industry. According to the definition of elasticity:

$$E = \frac{\Delta X / X}{\Delta Y / Y} = \frac{\Delta(X_1 + X_2)/(X_1 + X_2)}{\Delta Y / Y} = (\frac{Y}{X_1 + X_2})(\frac{\Delta X_1}{\Delta Y} + \frac{\Delta X_2}{\Delta Y})$$
$$= (\frac{X_1}{X_1 + X_2})(\frac{\Delta X_1 / X_1}{\Delta Y / Y}) + (\frac{X_2}{X_1 + X_2})(\frac{\Delta X_2 / X_2}{\Delta Y / Y}) \quad (1)$$
$$= \rho_1 E_1 + \rho_2 E_2$$

In Eq. (1), ρ_1 is the proportion of durable goods industry in the total export, ρ_2 is the proportion of non-durable goods industry. Eq. (1) shows that since ρ_1 >0.5 of the processing trade and larger than ρ_1 of general trade, if the export income elasticity of durable goods industry (E_1)is greater than that of non-durable goods industry (E_2),it will directly lead to the export income elasticity of processing trade greater than that of general trade, which means that the embeddedness of GVC will affect the export income elasticity through structural effect, so the following assumptions are proposed:

Theorem 1. *the export elasticity of durable goods is greater than that of non-durable goods, and the embeddedness of GVC will produce obvious structural effect, which will lead to the increase of export income elasticity.*

Bullwhip Effect: In real economic life, compared with general trade, the export income elasticity of durable goods and non-durable goods industries may be higher in the processing trade. In the meantime, the difference in the export income elasticity of durable goods and non-durable goods industries may be even prominent in the processing trade. This significance indicates that in addition to structural effects, it can also contribute to the heterogeneity of the GVC supply chain. Compared with general trade, imports of processing trade participating in the GVC supply chain can only be exported, instead of domestic sales. In order to more clearly reflect the characteristics of the GVC supply chain, this article assumes that all the import input (M_t)of a processing trade company will be used to produce export products and generate export value (X_t), of which imported raw materials are non-perishable, investment and inventory available.

$$M_t = X_t + I_t - I_{t-1} \quad (2)$$

In Eq. (2), $I_t - I_{t-1}$ indicates the change in the inventory of imported inputs. If $I_t - I_{t-1} > 0$, some imported inputs are converted into inventory, resulting inventories of imported inputs increase; if $I_t - I_{t-1}$ <0, then some of the inventory will be consumed and converted into inputs, resulting in inventories of imported inputs decrease; in long-term equilibrium, $I_t - I_{t-1} = 0$, at this time, $\overline{M} = \overline{X}$. Bring the long-term equilibrium into Eq. (2) and rearrange it.

$$\frac{M_t - \bar{M}}{\bar{M}} = \frac{X_t - \bar{X}}{\bar{X}}(1 + \frac{I_t - I_{t-1}}{X_t - \bar{X}}) = \frac{X_t - \bar{X}}{\bar{X}}(1 + \varphi_t) \quad (3)$$

The above Eq. shows that if $\varphi_t > 0$, the degree of export deviate from its steady state level will cause the import to deviate from its steady state level to a greater extent. In this case, $X_t - \overline{X}$ and $I_t - I_{t-1}$ change in the same direction, when the export is higher than its steady state value ($I_t - I_{t-1}$), the enterprise will respond by expanding its inventory ($I_t - I_{t-1} > 0$); on the contrary, when the export is lower than its steady state value ($X_t - \overline{X} < 0$), the enterprise will shrink the inventory ($I_t - I_{t-1} < 0$). The inventory adjusted mechanism of the GVC supply chain is divergent, which causes the "amplification effect" when demand fluctuations are transmitted from the lower end to the upper end of the supply chain, resulting in the import input to deviate more from its steady state, this effect is also known as the bullwhip effect. If $\varphi_t < 0$, it indicates that there is no bullwhip effect, and the inventory adjusted mechanism is convergent. The inventory adjustment reduces the impact of external demand fluctuations on import inputs, making import inputs closer to their steady state level. The inventory adjusted mechanism of the GVC supply chain makes GVC likely to have a bullwhip effect,

which was confirmed by Altomonte et al. (2012). On this basis, Gangnes et al. (2012) also confirmed the existence of the bullwhip effect of the GVC supply chain from the aspect of industry, Bray and Mendelson (2011) from the aspect of enterprise, and involved up to two-thirds of processing trade enterprises. Due to the characteristics of GVC's multinational fragmented production model, an enterprise may export or import intermediate goods. If the GVC supply chain has a bullwhip effect, it means that import fluctuation is greater than export fluctuation, and with the extension of GVC supply chain, the overall export income elasticity will be improved. In this regard, in order to simplify the analysis, this article assumes that there are only two enterprises A and B in the GVC supply chain, and they are strict upstream and downstream enterprises, of which enterprise A is the upstream company, imports (M_t)produce intermediate products (G_t), and all exports to the downstream enterprise B, the import of enterprise B is (G_t), and produce the final product (X_t)and export all of them. According to the Eq. (3), we can obtain:

As for enterprise A，

$$\Delta G_t / G_t = (1+\varphi)\Delta M_t / M_t \quad (4)$$

As for enterprise B，

$$\Delta X_t / X_t = (1+\varphi)\Delta G_t / G_t \quad (5)$$

Combining Eq. (4) and (5) can obtain Eq. (6).

$$E_A = \frac{\Delta G_t / G_t}{\Delta Y_t / Y_t} = (1+\varphi)\frac{\Delta X_t / X_t}{\Delta Y_t / Y_t} = (1+\varphi)E_B \quad (6)$$

In Eq. (6), E_A is the export income elasticity of enterprise A, E_B is the export income elasticity of enterprise B. Eq. (6)shows that in the GVC supply chain, the export income elasticity of enterprise A located in the upstream will change with the change of numerical value $(1+\varphi)$. When there is a bullwhip effect $(1+\varphi>1)$, the export income elasticity of enterprises will continue to increase, indicating that embedding GVC will lead to greater export income elasticity. After being negatively impacted by demand, it is first passed to GVC downstream enterprise B. At this time, the inventory adjusted mechanism of enterprise B causes the initial demand decline to be amplified and then continues to be passed to GVC upstream enterprise A along the GVC supply chain, while the inventory adjusted mechanism has further amplified the demand shock, which has produced the bullwhip effect, resulting in the increase of export revenue elasticity of enterprises. Withal, scholars such as Miaojie Yu (2011)also proved that industries with bullwhip effect have higher export income elasticity through different empirical methods, and proving the existence of bullwhip effect is to prove that demand shock will be magnified transmitting along the supply chain, that is, the fluctuation of imports is greater than that of the fluctuation of exports $(1+\varphi>1)$. Based on this, this article proposes the following assumptions:

Theorem 2. *The import fluctuation in the GVC supply chain is greater than that of the export fluctuation, and there is a bullwhip effect in the embeddedness of GVC, which will cause Chinese export income elasticity to further increase.*

Compared with the stationary phase of economic, the fluctuant phase of economic will bring greater uncertainty, and most enterprises will adopt a wait-and-see strategy, which will cause investment delays. Due to the overlapping effects of investment delays and economic fluctuations, judgmental errors of the enterprise in their “rational expectations” of the future economic situation will increase. Enterprises will make larger inventory adjustments in order to reduce risks, and the heterogeneity of the GVC supply chain itself may cause greater import fluctuation. Based on this, in the period of severe economic fluctuations, the bullwhip effect of the GVC supply chain may be more significant. Existing research also shows that the impact of the bullwhip effect is different when facing different demand fluctuations. For example, Altomonte et al. (2012) found that during the financial crisis of 2007-2009, the bullwhip effect of French processing trade enterprises was significant, and the fluctuation of imports was greater than the fluctuation of final demand; not coincidentally, Alessandria et al. (2011)also found that in the period of economic fluctuations, due to the existence of intermediate product trade, the bullwhip effect of processing trade enterprises is more obvious with American data. Taking Wal-Mart supermarket as an example, the mechanism of the bullwhip effect of the GVC supply chain during economic fluctuations is analyzed in detail. Based on this, this article proposes:

Theorem 3. *When the other conditions are the same, the bullwhip effect of the embeddedness of GVC will be more significant when the demand fluctuates sharply.*

Data Description

Data Source: The data in this article originates from the Industry Statistical Data, the CEPII database and China Customs Database from 2001 to 2015.Based on the perspective of GVC, this paper sorts and filters the data according to the dimension of industry-time-processing method. This article divides the industry data in the China Customs Import and Export Database from 2001 to 2015 into 21 industries according to customs standards, deletes 30 weapons industry values, and obtains comprehensive data including industries, export values, import values, and trade methods. Based on this, 630 pieces of export sample and import sample data of the industry-time-processing method were obtained, involving 21 industries with a time span of 15 years. The processing methods mainly include processing trade and general trade. On this basis, this article selects the industry classification data of China exports to countries around the world from 2001 to 2015 and the distance between China and exporting countries, recalculates the foreign income, and finally obtains 315 industry-country-time samples.

Dependent Variables

Export Volume (x_{it}): In the process of inspecting whether the embeddedness of GVC increases the elasticity of export revenue and whether GVC has structural effect, the export is taken as the Predicted Variable. The actual exports in 2001-2015 are adopted in this paper to represent the export demand volume in the model, and the specific empirical conclusions will not be affected. In the specific regression equation, it can be either the export value of processing trade (PT) or the export value of general trade (GT). When GVC is embedded,

the predicted variables choose the export volume of processing trade; when GVC is not embedded, the predicted variables choose the export volume of general trade, and determine the impact of the embeddedness of GVC on export income elasticity by comparing the gap between the two.

Import Volume (m_{it}): In the process of inspecting whether there is bullwhip effect in GVC supply chain and its significance in the period of economic fluctuation, the import volume is taken as the predicted variable. When GVC is embedded, the PT import volume is selected; when GVC is not embedded, the GT import volume is selected. By comparing the gap between the two, we can test whether there is bullwhip effect in GVC supply chain. Typeset sub-subheadings in medium face italic and capitalize the first letter of the first word only.

Explanatory Variable

Foreign Income (Y): In this paper, weighting the GDP of China's major trading partners as an alternative variable of foreign income(Y). Considering the proportion and geographical distribution of China's exports to all countries in the world from 2001 to 2015, this paper selects the United States, the European Union, Japan, Australia, Russia, Hong Kong and South Korea as examples, with an average annual export proportion of more than 70%. Referring to the gravity model, this paper calculates the proportion of each trading partner country in the calculation of foreign income, that is, $Y_{it} = K_{it} \times \frac{GDP_{0t} \times GDP_{it}}{R^2}$. Among them, GDP_{0t} represents China's GDP in t year and GDP_{it} represents the GDP of i country/region in t year, and take $k_{it} / \sum k_t$ as the weight. The basis is that distance plays an important role in the choice of processing trade, and the gravity model can highlight the influence of foreign GDP on exports. Therefore, foreign income is equal to Y= $\sum i \times GDP_i$, $i = k_{it} / \sum k_t$.

Exchange Rate (R): This paper will create exchange rates for 21 industries. First of all, determining the types of currencies in the basket. In this paper, the currencies of the United States, the European Union, Japan, Australia, Russia, Hong Kong and South Korea are selected as the basket currencies. To some extent, the currency changes selected in this paper can represent the global exchange rate changes. Secondly, calculating the weight of currencies in the basket by industry through $i_{kt} = x_{kit} / x_{it}$. Among them, i_{kt} represents the weight of k country/region in t year, x_{kit} represents the export volume of i industry from China to k country/region, and x_{it} represents the total export volume of China in i industry in t year. It is worth noting that since China's total exports to the country/region of currencies in the basket are not 100%, the sum of exports to the country/region of currencies in the basket is regarded as China's total exports in the industry so as to meet the requirement that the sum of weights is 1. Finally, the index weighted method is used to calculate the exchange rate index of each industry in t year, that is, R= $\sum i_{kt} \times r_{kit}$, of which r_{kit} represents the exchange rate of i industry of k country/region in t year.

Controlled Variables: Referring to the traditional influencing factors of export income elasticity in the existing research results, the following controlled variables are also considered in this paper:

Total Factor Productivity (TFP): In this paper, TFP_t intended to use Solow Residual Method to conduct calculation. The basic idea is to calculate the TFP growth by the residual of the output growth rate after deducting the growth rate of each input factor after estimating the total production function. Assuming that capital and labor are the only important inputs, the calculation method is using the logarithmic form of Cobb Douglas production function to fit the output, and then the estimated value is obtained: $\hat{y}_t = \hat{a}l_t + \hat{b}k_t + \mu$; TFP is equal to the difference between actual output and estimated output, that is, $TFP_t = y_t - \hat{y}_t$. Among them, y_t , l_t and k_t respectively represent the logarithm of output, labor and capital.

Outward Foreign Direct Investment (OFDI): The data of OFDI in this paper comes from the industry statistical yearbook and China statistical yearbook. As a controlled variable at the overall level, there is no calculation by industry.

Fluctuations in Exchange (Flu): Fluctuations in exchange refers to the uncertainty that affects the production and investment of enterprises to affect export trade. According to the practice of Héricourt and Poncet (2013), the standard deviation of the first-order difference of the logarithm of exchange rate is used to measure the fluctuations in exchange. $Flu = std.dev\left[\ln rer_{t+1}, \ln rer_t\right]$, of which t represents 2001 to 2005 year. In addition, in order to control the influence of industry characteristics on export, this paper adds individual fixed effect to control the regression, and introduces time fixed effect into the model to control the influence of different export time on the regression results. Based on this, the statistical description of each variable in this paper is shown in *Table 1.*

Benchmark Regression

Model Setup: In order to inspect whether the embeddedness of GVC is able to significantly improve the elasticity of export revenue, this paper adopts the widely used C-D export demand model based on the imperfect substitute model of Keynes, which is defined as:

$$x_{it} = y_{it} \times r_{it} \qquad (7)$$

In Eq. (7), x_{it} represents the demand of foreign countries for Chinese goods in i industry in t year, r_{it} represents the relative price of Chinese and foreign goods in i industry in t year, y_{it} represents the foreign income in i industry in t year. Considering that the explanatory variable of exchange rate is a non-stationary sequence, on the basis of consulting the practice of previous literature (Li et al., 2015), taking the logarithm of the core variables of export volume, exchange rate and foreign income in In Eq. (7), to carry out the first-order difference processing. The following benchmark models are obtained:

$$\Delta \ln x_{it} = \alpha \Delta \ln y_{it} + \beta \Delta \ln r_{it} \qquad (8)$$

In Eq. (8), α represents the income elasticity of export and β represents the price elasticity of export.

Table 1. Description on Variable Statistics

Variable	Sample Capacity	Mean Value	Standard Deviation	Minimum Value	Maximum Value
PT Export	288	0.082	0.482	-4.148	4.434
GT Export	288	0.142	0.275	-1.848	3.071
PT Import	198	0.265	1.065	-4.431	7.147
GT Import	217	-0.023	1.681	-8.841	10.427
Foreign Income（Y）	308	0.006	0.291	-1.696	3.692
Exchange Rate（R）	308	-0.003	0.158	-0.517	1.882
Total Factor Productivity（TFP）	286	-0.006	0.042	-0.091	0.082
Outward Foreign Direct Investment（OFDI）	264	0.327	0.266	0.011	0.802
Exchange Fluctuations（Flu）	286	0.029	1.751	-6.911	5.398

Table 2. Regression Results of Benchmark

	Benchmark		GMM		Proxy Variable	
	PT	GT	PT	GT	PT	GT
Y	0.838***	0.210**	1.246***	0.400***	1.932**	0.693**
	（0.255）	（0.091）	（0.203）	（0.144）	（0.818）	（0.284）
R	-1.335***	-0.418**	-1.522***	-0.469**	-2.548***	-0.812***
	（0.419）	（0.181）	（0.371）	（0.230）	（0.882）	（0.313）
TFP	1.268	1.611***	1.657**	1.581***	0.044	1.212***
	（0.790）	（0.300）	（0.747）	（0.482）	（0.726）	（0.335）
OFDI	0.215*	0.051	0.206*	0.253***	-0.237	0.014
	（0.129）	（0.072）	（0.121）	（0.077）	（0.182）	（0.075）
Flu	-0.006	-0.003	-0.020	0.005	-0.014	-0.002
	（0.011）	（0.004）	（0.017）	（0.011）	（0.009）	（0.004）
FE	YES	YES			YES	YES
N	225	225	225	225	225	225
R2	0.111	0.128			0.166	0.213

Standard errors in parentheses，$^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

In this paper, the other influencing factors of export income elasticity are introduced into the benchmark Eq. (8), as control variables, and the extended export function expression is obtained, that is,

$$\Delta \ln x_{it} = \alpha_0 + \alpha_1 \Delta \ln y_{it} + \alpha_2 \Delta \ln r_{it} + \alpha_3 Controls + \varepsilon_{it} \quad (9)$$

In Eq. (9), *Controls* represents all control variables.

Benchmark Regression: In this paper, the measurement model is established at the industry level. Besides, the export industry data are divided into processing trade and general trade. The following equations are estimated as follows:

$$\Delta lnx_{it} = a_0 + a_1 \Delta lnY_{it} + a_2 \Delta lnr_{it} + a_3 \Delta lnTFP_t + a_4 \Delta lnOFDI + a_4 \Delta lnFlu + u_i + u_t + e_{it} \quad (10)$$

In Eq.(10), i represents the export industry and t represents the year of export, and control industry level fixed effect (υ_i) and time fixed effect (υ_i) to ensure the stability of results. In order to eliminate the adverse effects of heteroscedasticity and sequence correlation, Hausman Test was used to determine the fixed effect model (FE). At the same time, in order to test the impact of GVC embeddedness on China's export income elasticity, each column includes two regression equations, that is, the export volume of processing trade as the explained variable and the export volume of general trade as the predicted variable, which are used to distinguish the heterogeneity of processing trade and general trade. The regression results are shown in *Table 2*. From the results of explanatory variable, China's export elasticity of processing trade is 0.838 and that of general trade is 0.210, which indicates that GVC embeddedness will increase the export elasticity by 399%; meanwhile, the export price elasticity of processing trade is -1.335 and that of general trade is -0.418, which shows that the export price elasticity of processing trade is greater than that of general trade. This result shows that GVC embeddedness will make exports more sensitive and the export price elasticity will increase. Specifically, processing trade mainly depends on exports and participation in the production process, so these factors are more sensitive to exchange rate changes. From the results of the controlled variable, the coefficient of Total Factor Productivity is positive in both processing trade and general trade, and it is very significant in general trade. This shows that increasing Total Factor Productivity will help to expand exports, especially for general trade. The coefficient of Outward Foreign Direct Investment is positive, which means that the change of foreign income can be absorbed by the change of direct investment. However, in the later Robust Test, the coefficient appears negative value, which indicates that the relationship between Outward Foreign Direct Investment and export should be analyzed according to the specific situation. The influence of Fluctuations in Exchange is not significant, and the coefficient is very small. This may be due to the large difference between the data of Fluctuations in Exchange and the magnitude of Predicted Variable. Although regression analysis can be carried out after differential treatment, the value of Fluctuations in Exchange after differential treatment is very close, which cannot fully reflect its impact. The negative coefficient indicates that the fluctuation of exchange rate is not conducive to the growth of export trade. The above benchmark results show that exports are positively correlated with incomes and negatively correlated with relative prices. In addition, the export income elasticity of processing trade is always significantly greater than that of general trade, which shows that GVC embeddedness significantly increases the export income elasticity of China.

Robust Test: In order to verify the credibility of the benchmark regression results, this paper adopts the methods of changing the measurement model and changing the main explanatory variable to test the robustness.

GMM Method: Roberts and Tybout (1997) found that once an enterprise enters the export market, its import and export behavior will be sustainable, and the equation may be endogenous. The first-order plus dead-time is introduced into the equation as a tool variable, and the GMM method is used to solve the endogenous problem. Table 3 shows the estimated result of GMM. Compared with the estimated result of FE, the significance of the controlled variable and the overall effectiveness of the model are enhanced, and the coefficient value, symbol and significance of the explanatory variable shows a strong robustness. Among them, the export income elasticity of processing trade is 1.246, and that of general trade is 0.400, which indicates that GVC embeddedness will increase the export income elasticity by 311%.

Use Different Proxy Variable: In order to further test the robustness of the model, this paper redefines the weight of foreign income based on the export share of each trading partner, that is, weight of trading partners $= x_{kit} / x_{it}$. x_{kit} represents the export volume of i industry to k country in t year, x_{it} represents the total export volume of i industry in t year in China, and uses the index weighting method to calculate the foreign income (y_{it})= $\sum i \times GDP_i$. The regression results in Table 3 show that after changing the measurement method of foreign income, the main explanatory variable is still effective, and again verify the robustness of the conclusion that GVC embeddedness will increase the elasticity of export income.

Influence Mechanism Test: On the basis of empirical test on whether GVC embeddedness will affect export income elasticity, this paper will further study how GVC embeddedness will affect export income elasticity, and test the difference of GVC industry distribution (structural effect) and the heterogeneity of GVC supply chain (bullwhip effect) according to theoretical hypothesis 1 and hypothesis 2.

GVC Structure Effect: The core problem of Structure Effect of GVC is to test whether the export income elasticity of durable goods industry is higher than that of non-durable goods industry. In this paper, the Dummy Variables is set as dur , when $dur = 1$ that represents durable goods industry and when $dur = 0$, it represents non-durable goods industry. According to whether the interaction between durable goods and foreign income is significant, we can judge whether the export income elasticity of durable goods industry is higher than that of non-durable goods industry. Therefore, the estimated model is as follows:

$$\Delta lnExport_{it} = a_0 + a_1 \Delta \ln Y_{it} + a_2 \Delta \ln Y_{it} * dur + a_3 \Delta lnr_{it} + a_4 Controls + u_i + u_t + e_{it} \quad (11)$$

In order to better analyze the difference of export income elasticity between durable goods and non-durable goods, and increase the robustness of the conclusion, this paper not only conducts group inspection according to different export methods, but also respectively conducts FE and GMM inspection. The results are shown in *Table 3*. It shows that the interaction item (*Y*dur*) between durable goods and foreign income is significantly positive, whether based on the grouped samples of processing trade exports and general trade exports, or based on the two measurement methods of FE and GMM. This means that the export of durable goods industry is more sensitive to foreign income changes, and the export income elasticity of durable goods industry is higher than that of non-durable goods industry, which is consistent with the prediction of hypothesis 1 in the transmission mechanism. The benchmark regression results of FE model show that the export income elasticity of durable goods industry in processing trade is 0.803, higher than that of non-durable goods industry (0.793); similarly, the export income elasticity of durable goods industry in general trade is 0.359, higher than that of non-durable goods industry (0.352). It can be seen from the typical facts that China's processing trade is mainly concentrated in the durable goods industry. In 2015, the processing trade accounted for 65.2% of the export of durable goods, but only 34.8% of the export of non-durable goods. That is to say, the industry distribution characteristics of GVC make the durable goods account for a relatively high proportion in its export structure. From the above two aspects, it can be concluded that GVC embeddedness will increase the elasticity of export income through structural effect.

In addition, the export income elasticity of durable goods (0.803) and non-durable goods (0.793) in the sample of processing trade is higher than that of durable goods (0.359) and non-durable goods (0.352) in the sample of general trade, and the coefficient of interaction item (*Y*dur*) between durable goods and foreign income in the sample of processing trade is 0.010, which is higher than that in the sample of general trade sample 0.007. This data shows that the difference of income elasticity between durable goods industry and non-durable goods industry is more significant in processing trade. Based on this, we speculate that in addition to the structural effect of processing trade, there are other influence mechanisms to promote the increase of export income elasticity of processing trade, which will be confirmed in the test of the bullwhip effect of GVC supply chain. In order to increase the credibility of the conclusion that GVC has structural effect, we use GMM method and remeasure foreign income to test the robustness. The estimated result shows that the interaction item (*Y*dur*) between foreign income and durable goods is still significantly positive in both processing trade and general trade. This shows that the export income elasticity of durable goods industry is greater than that of non-durable goods, which is robust, and verifies the hypothesis 1 again.

GVC Bullwhip Effect: In order to test whether there is bullwhip effect in the supply chain of processing trade and whether its demand shock has amplification effect when it is transmitted to the front of the supply chain, this paper will test whether the fluctuation of PT import is greater than that of PT export. If it is greater than, it indicates that there is a bullwhip effect in GVC supply chain. For this purpose, the following estimation model is needed:

$$\Delta lnImport_{it} = \alpha_0 + fe + \alpha_1 \Delta lnrx_{it} + \alpha_2 Controls + \upsilon_i + \upsilon_t + \varepsilon_{it} \quad (12)$$

In Eq. (12), the predicted variable $\Delta \ln m_{it}$ represents the import fluctuation, and the explanatory variable $\Delta \ln x_{it}$ represents the export fluctuation.

Table 3. Test Result of Structure Effect of GVC

	Benchmark		GMM		Proxy Variable	
	PT	GT	PT	GT	PT	GT
Y	0.793	0.352	0.995	0.237	0.847***	0.024
	（2.429）	（1.077）	（0.773）	（0.513）	（0.283）	（0.111）
Y*dur	0.010***	0.007***	1.085***	0.688***	0.010**	0.473***
	（0.003）	（0.002）	（0.328）	（0.214）	（0.004）	（0.119）
R	-1.292	-0.493	-1.316*	-0.424	-1.719***	-0.350*
	（2.262）	（0.798）	（0.759）	（0.489）	（0.471）	（0.204）
TFP	0.255	1.265	0.111	1.198**	-2.126	1.683***
	（2.356）	（1.294）	（0.818）	（0.548）	（9.316）	（0.278）
OFDI	0.125	0.184**	0.190	0.225***	0.849***	0.054
	（0.174）	（0.073）	（0.133）	（0.084）	（0.185）	（0.063）
Fluc	-0.010	-0.003	-0.019	-0.006	-0.002	-0.001
	（0.013）	（0.007）	（0.017）	（0.012）	（0.011）	（0.004）
FE					YES	YES
N	225	225	204	204	225	225
R2	0.033	0,085			0.147	0.241

Standard errors in parentheses，$^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

Table 4. Test Result of GVC Bullwhip Effect

	FE Model		GMM Model		DID Model
	PT Import	GT Import	PT Import	GT Import	PT Import
Export	1.289**	0.798***	2.446***	0.778***	1.723***
	（0.528）	（0.112）	（0.651）	（0.072）	（0.639）
Lag Export					1.376**
					（0.546）
TFP	3.104	-0.603	10.147***	-0.103	0.351
	（2.241）	（2.611）	（3.108）	（1.584）	（2.451）
OFDI	-0.184	0.129	-4.919**	-0.045	-0.483**
	（0.337）	（0.405）	（1.965）	（0.328）	（0.234）
dt					0.617***
					（0.106）
du					1.195***
					（0.225）
du*dt					0.595**
					（0.284）
N	136	217	138	174	135
R2	0.061	0.218			0.229

Standard errors in parentheses，$^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

The controlled variables are the same as above, and industry characteristic υ_i and time characteristic υ_t stay the same. The regression results are shown in *Table 4*. The result of FE model shows that the regression coefficient (1.289) of the explanatory variable PT export volatility is greater than 1, indicating that PT export volatility will lead to a greater extent of PT import volatility. It shows that there is a bullwhip effect in GVC supply chain, and hypothesis 2 holds. At the same time, the regression coefficient of GT export volatility (0.798) is less than 1, indicates that the GT export volatility does not lead to GT import volatility to a greater extent. It shows that there is no bullwhip effect in general trade supply chain. This further proves that only GVC supply chain has the bullwhip effect, so embedding GVC will lead to the increase of export income elasticity through the unique bullwhip effect of supply chain. Similarly, the robustness test result of GMM model also shows that the regression coefficient of export volatility in processing trade (2.446) is greater than 1, while the regression coefficient of GT export volatility (0.778) is less than 1, which proves that there is a bullwhip effect in GVC supply chain, and there is no bullwhip effect in general trade supply chain. It is worth mentioning that the controlled variables are the main factors influencing the import and export of the supply chain based on the existing research, and the coefficient of the control variables under the two methods is not significant (except GMM Estimation in the processing trade samples).

In addition, since the fluctuation in exchange exists collinearity, it will be automatically deleted in Stata regression which also shows that external factors have little effect on the bullwhip effect in GVC supply chain.

Extension: GVC Bullwhip Effect in Economic Fluctuation Period: In order to test whether GVC bullwhip effect is more significant in the period of economic fluctuation, this paper uses the research of Altomonte et al. (2012) and Gangnes et.al. (2012) as a natural experiment. In this experiment, the double difference method (DID) was used to analyze the samples, and the bullwhip effect of GVC supply chain in the period of economic fluctuation and economic stability was deeply investigated, and then whether the bullwhip effect of processing trade was more significant in the period of economic fluctuation was tested. For this reason, this paper only studies the processing trade which has been tested before, excluding the general trade which does not have the bullwhip effect, and assumes that the bullwhip effect among the processing trade industries has a common trend.

Take the food industry with rigid demand and little impact of economic fluctuation as the “control group” and other processing trade industries as the “treatment group”. It can be found from the above long whip effect test that whether the coefficient of the only explanatory variable exit PT export is

greater than 1 determines whether GVC has the long whip effect, and the value of the coefficient can represent the size of the long whip effect to a certain extent. Based on this, we establish the DID regression equation as follows:

$$\Delta lnPTimport_{it} = a_0 + a_1 \Delta lnx_{it}^{gvc} + a_2 du + a_3 dt + a_4 du \times dt + a_5 Controls + u_i + u_t + e_{it} \quad (12)$$

In Eq. (12), the variable indicates whether the industry is a dummy variable of food industry. If it is a food industry, du = 1, otherwise du = 0. The variable dt indicates whether the year is a dummy variable from 2007 to 2008. According to the change of the economic policy uncertainty (EPU), 2007-2008 is the period of economic fluctuation brought by the financial crisis. Therefore, if the year t is after 2007 (including 2007), $dt = 1$, otherwise $dt = 0$. The test results of did in *Table 4* show that the coefficient of du is positive, indicating that the bullwhip effect of the experimental group is higher than that of the control group, and the export income elasticity of the non food industry is higher than that of the food industry; the coefficient of dt is significantly positive, indicating that the bullwhip effect of the treatment group and the control group is on the rise in time dimension, and in 2007-2008, the bullwhip effect of all industries shall be increased; $du \times dt$ is significantly positive, which indicates that the bullwhip effect of the post-treatment group is higher than that of the control group, that is to say, the bullwhip effect of processing trade is more significant in the period of severe economic fluctuation. It proved hypothesis 3.

Conclusion

According to the existing research results and China's actual situation, this paper regards processing trade as embedded GVC and general trade as not embedded GVC. On this basis, using the customs import and export data of different industries from 2001 to 2015, this paper studies the impact of GVC embeddedness on export income elasticity from both theoretical and empirical levels, and reveals the possible mechanism behind it. The results show that participation in division and cooperation of GVC will improve the elasticity of China's export income. Even after changing the measurement model and the measurement method of main explanatory variables, this conclusion is still robust. This result is attributed to the structural effect and bullwhip effect of GVC embedding. The former refers to that GVC embeddedness is mainly distributed in durable goods industry, and the export income of durable goods industry is significantly higher than that of non-durable goods industry, resulting in the increase of export income elasticity after embeddedness of GVC; the latter means that the impact of external demand will be amplified along the transmission of supply chain, that is to say, the fluctuation of import is greater than that of export, which significantly improves the elasticity of China's export income, and this bullwhip effect is more significant in the period of economic fluctuation. The practical meaning of the above conclusion is that China is deploying a new round of expanding opening up and the value chain of the countries along the route of "One Belt, One Road" is being further strengthened and upgraded. In this process, we need to correctly deal with the relationship between the foreign GVC embeddedness of China's industries and the elastic change of domestic export income, and take targeted measures to reduce the possible risks of GVC embeddedness.

Firstly, the change of export income elasticity should be considered when GVC is embedded in Chinese industry. With the continuous development of open economy, dividing the work of GVC is an unavoidable objective fact. Promoting GVC embeddedness in China's industry is conducive to increasing export volume, but we should also consider the risk of increasing export income elasticity. With the implementation of some developed countries' measures such as increasing tariffs and restricting imports, especially the escalation of trade frictions between China and the United States. China's participation in GVC industry is the first to be affected. Therefore, when promoting GVC embeddedness in the industry, we should not be passive, but actively estimate the risk return. Secondly, we should pay attention to the optimization of export structure, and promote the balanced distribution of processing trade from durable goods industry to durable goods and non-durable goods industry. Processing trade is the most important form of GVC embeddedness in Chinese industry, and mainly focuses on durable goods industry. The imbalance of industry distribution increases the dependence of GVC export on foreign economy, which leads to the increase of export income elasticity. Therefore, promoting the export structure of processing trade to balance the distribution of durable goods and non-durable goods will not only improve the embeddedness of China's GVC industries, but also reduce the sensitivity of China's processing trade to foreign economic fluctuations to a certain extent. Thirdly, pay great attention on the export fluctuation of GVC embedded industry in the period of economic fluctuation. In the period of economic fluctuation, the export fluctuation may be more intense because of the bullwhip effect of GVC embeddedness. Therefore, in the period of global economic depression, the government should improve the early warning and monitoring of GVC embedded industry exports, and pay attention to dig up the domestic economic growth momentum. At the same time, we should also pay attention to the reasonable adjustment of the domestic economic operation and coordinate the two-way and reasonable development at home and abroad.

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