Research on the Relationship between Global Value Chain and Environmental Pollution: Based on Chinese Firm-Level Data

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Abstract: Global value chain (GVC) is not only value-added distribution chain but also pollution-sharing chain closely related to benefit distribution. With the deepening of firms participating in GVC and under the burden of severe environmental pollution, There is a question on our minds, that is whether smile curves in global value chains bring crying curves in pollution chains. This paper empirically tested the relationship between GVC participation and environmental pollution from firm-level perspective, using the matching data of the China Industrial Firms Database, China Firms Pollution Database, and UIBE Database from 2000 to 2012. The results show that the GVC participation and GVC length have different effects of environmental pollution. GVC participation have negative effects of pollution, while GVC length have positive effects of pollution. Both effects of environmental pollution are influenced by GVC models. This paper provide policy suggestions for environmental protection from the perspective of adjusting GVC participation strategy.

Keywords: Gvc; Pollution; Forward-Linkage; Backward-Linkage

1. Introduction

In the background of vertical specialization, international trade activities shift commodity production from final consumption areas to emerging production areas. At the same time, production-related pollution emissions also shift, thus changing the spatial and temporal distribution characteristics of pollution [1-3]. This means that GVC production activities may present heterogeneous environmental pollution characteristics [4-5]. Firms take advantage of their comparative advantages to focus on a particular production process. Since the production processes are mainly concentrated in developing countries, developing countries will cause more pollution, and the smile curves in GVCs may become the crying curves in pollution chains. Is environmental pollution an inevitable result of firm participation in GVC? How to effectively realize the win-win goal of economic development and environmental protection.

2. Literature Review

The relationship between international trade and environmental pollution has always been a very attractive topic of economic research. Environmental Kuznets Curve (EKC), Pollution Haven Hypothesis (PHH) and other classic environmental economics propositions are derived from the study of trade-related issues. EKC can be traced back to Grossman and Krueger's (1991)[6] study on the environmental impact of the North American Free Trade Agreement. They examined air pollution data from 43 countries and found that pollution levels rise and then fall as per capital are proposed. Some scholars' studies support the establishment of EKC [7], and some scholars denied the existence of EKC through empirical studies [8]. PHH also originated from the study of international trade issues. PHH is supported by a large number of theoretical and empirical studies [9], while some studies using different countries, different pollution indicators and different methods do not always support the establishment of PHH [10]. The reason why PHH is not established may be that the trade flow is still mainly determined by factor endowment rather than the intensity of environmental regulation. Antweiler et al. (2001) [11] constructed a new theoretical model combining factor endowment theory and PHH, decomposed the scale, structure and technical effects of trade on environmental pollution. This theoretical framework has

gradually become the mainstream paradigm of the impact of trade on the environment and has been widely used at home and abroad. Studies on the relationship between GVC and environmental pollution mainly stay at the macro-level. For example, Lv and Lv (2019) [12]made a preliminary discussion on the relationship between GVC and carbon emissions based on China's industrial sector level, without involving the micro firm level. Cai et al. (2019)[13] believed that GVC backward-linkage would increase CO_2 emissions, while GVC backward-linkage presented a U-shaped relationship with CO2 emissions. Xie et al. (2018)[14] analyzed the relationship between GVC and carbon emissions from the sector level, and believed that GVC had a positive impact on reducing carbon emissions of China's manufacturing industry.

3. Theoretical Framework

Based on the existing literature and combined with the theoretical framework of Grossman and Krueger (1991), we believe that GVC participation will affect environment pollution through three mechanisms: The Scale, Structure, and Technology Effects.

3.1 Scale Effect

GVC participation helps domestic firms to integrate into the international market, expand the market scale, and further release the domestic production potential. As part of GVC, domestic production became more specialized and economies of scale were realized. Both of these aspects mean the expansion of production scale. However, in the GVC division of labor, developing countries mainly undertake processing and assembly links with low added value, small profit and high energy consumption, so the expansion of production scale means greater resource input and environmental pollution.

3.2 Structural Effect

The extension of GVC length will on the one hand introduce foreign advanced technology and production experience through import learning effect, and on the other hand force domestic firms to improve production technology and upgrade production equipment through export competition effect, thus promoting the transformation and upgrading of domestic industrial structure. The optimization and upgrading of industrial structure is conducive to the optimal allocation of capital, labor and other production factors in the inter-industry or intra-industry, and then accelerate its transformation and evolution to the direction of green and low-carbon. At the same time, the carbon reduction effect of industrial structure upgrading has been generally confirmed. Therefore, prolonging the participation length of GVC can inhibit environmental pollution by promoting industrial structure upgrading.

3.3 Technology Effect

In terms of technology effect, with the extension of GVC length, firms can access the advanced technology and management experience of GVC-leading firms, so as to obtain greater technology spillover, thus improving energy efficiency and curbing environmental pollution. To be specific, firstly, technology spillover. Through the externality of technology, extending GVC length helps firms to obtain technology spillover and transfer, thus reducing unnecessary energy consumption and improving energy utilization efficiency. Secondly, "policy" forces GVC firms to carry out technological innovation in countries with more stringent environmental protection standards and energy use requirements. Energy efficiency will be improved in invisible ways. Thirdly, competition effect. In the face of competitive pressure from the global market, GVC firms need to constantly carry out technological innovation and product upgrading if they want to keep their competitive advantages. Therefore, extending GVC length can inhibit environmental pollution by promoting technological progress and improving energy efficiency.

4. Empirical Test

4.1 Model Establishment

According to the research purpose of this paper and the research hypothesis proposed in the theoretical framework, the benchmark econometric model is set as follows:

$$Pol_{it} = \alpha + \beta_1 GVC_{it} + \gamma_1 C_t + IV + TV + \varepsilon_{it} \quad (1)$$

In the above formula, the subscripts i and t represent the firm and time respectively. The explained variable *Pol* represents the firm

pollution emission intensity. Core explanatory variable *GVC* represents firm GVC index, including firm GVC participation degree and GVC participation length. Among them, firm GVC participation degree is further divided into forward participation degree and backward participation degree; firm GVC length can also be divided into forward-linkage length and backward-linkage length. *C* represents the set of control variables; *IV* and *TV* represent firm fixed effect and year fixed effect respectively. ε is the error term.

4.2 Variable Description

4.2.1 Explained variable: firm pollution emission intensity

Pollution emissions intensity based on the firm pollution emissions per unit of output. In order to fully capture the firms' pollution situation, this paper selects four main pollutants that cause air pollution. Using chemical oxygen demand, industrial waste gas, smoke and dust four typical pollutants to construct the comprehensive index of firm pollution emission intensity, the above four indexes are synthesized based on principal component analysis, the indexes are used as *Pol*.

4.2.2 Explanatory variables: firm GVC participation degree and firm GVC participation length

Based on the GVC measurement theory proposed by Wang Zhi [15] this paper adopts firm GVC participation degree and length to characterize the GVC index.

(1) GVC participation degree

On the one hand, GVC Participation Indexes at sectoral level (Forward Linkage)**:**

$$Pt\_F=\frac{V\_GVC}{\hat{V}X}=\frac{V\_GVC\_R}{\hat{V}X}+\frac{V\_GVC\_D}{\hat{V}X}+\frac{V\_GVC\_F}{\hat{V}X} \quad (2)$$

GVC forward participation reflects the proportion of domestic added value in the export of intermediate goods in the added value of national sectors divided by industry. The larger the value is, the higher the ratio of added value in the export of intermediate goods is. The export of intermediate products can be divided into: the part directly absorbed by the importing country; that is returned and absorbed by the exporting country; indirectly absorbed by the importing country or re-exported to a third country.

On the other hand, GVC Participation Indexes at sectoral level (Backward Linkage):

$$Pt\_B=\frac{YGVC}{Y}=\frac{YGVC\_R}{Y}+\frac{YGVC\_D}{Y}+\frac{YGVC\_F}{Y} \quad (3)$$

Backward participation reflects the proportion of domestic and foreign added value in the import of intermediate products in the gross product value. The larger this value is, the higher the proportion of foreign added value in the import is. The import of intermediate goods can be divided into: the part directly used by the importer to produce the final product; the part used to produce final products for domestic consumption or export; the part that produces exports that are eventually absorbed by third countries.

(2) GVC participation length

On the one hand, forward-linkage GVC length: Based on the perspective of forward-linkage, the matrix form of value chain length is:

$$pLv=\frac{\hat{V}BB\hat{Y}\mu}{\hat{V}B\hat{Y}\mu}=\frac{\hat{V}BBY}{\hat{V}BY}=G\mu' \quad (4)$$

In the above formula, G Gaussian inverse. U is a 1*N matrix, all the entries are 1. According to whether they participate in the GVC division of labor or not, the length of value chain can be divided into domestic part, traditional trade part and GVC part, among which the domestic part and traditional trade part do not participate in the GVC division of labor, and the decomposition process is as follows:

$$PLv=PLv\_D+PLv\_RT+PLv\_GVC \quad (5)$$

In the above formula, *PLv_D, PLv_RT, PLv_GVC* represent the length of part of value chain within China, part of value chain of traditional trade and part of value chain of GVC respectively. *PLv_GVC* is one of the explanatory variables in this paper.

On the other hand, backward-linkage GVC length: Based on the perspective of backward-linkage, the matrix form of value chain length is:

$$PLy=\frac{Xy}{Y}=\frac{u\hat{V}BB\hat{Y}}{u\hat{V}B\hat{Y}}=\frac{VBB\hat{Y}}{VB\hat{Y}}=uB \quad (6)$$

In the above formula, *B* is leontief inverse matrix. U is a 1*N matrix, all the entries are 1. Similarly, the length of value chain can be divided into domestic part, traditional trade part and GVC part according to whether they participate in GVC production division, as shown below:

$$PLy=PLy\_D+PLy\_RT+PLy\_GVC \quad (7)$$

In the above formula, *PLy_D, PLy_RT*,

PLy_GVC represent the length of part of value chain within China, part of value chain of traditional trade and part of value chain of GVC in the backward association respectively. *PLy_GVC* is one of the explanatory variables in this paper.

After obtaining GVC participation degree and length at sectoral level, the degree and length at the firm level can be calculated according to the weight relationship between the firm and the sector to which it belongs. Specifically, an firm may produce a variety of products in different sectors. In this paper, the 8-bit HS code export information of subdivided customs data is used to calculate the weight coefficient of the firm's products in different sectors according to the classification of the firm's export products, and then the weighted average of the degree and length of the firm is obtained:

$$\sum_{i=1}^{N} GVC_i X_{ij} / X_j \quad (8)$$

In the above formula, X_j represents the total export of firm j, and X_{ij} represents the export of firm j within sector i. GVC_i represents GVC participation degree or length of sector i.

4.2.3 Control variables: Macro-control variables and Micro-control variables.

Macro-control variables include: (1) geographical location (*City*), which is represented by the city where the firm is located. Geographical features are not only an important factor affecting air pollution, but also play an important role in international trade and other economic activities (Eaton and Kortum, 2002). (2) Time dummy variable. The financial crisis period (T_1) and WTO accession period (T_2) were selected as two time dummy variables. T_1 is 1 during the financial crisis period from 2007 to 2009, and 0 in other years. T_2 is 1 after China joined the WTO in 2001 and 0 before it.

Micro-control variables are selected to represent the characteristics of the firm, including: (1) firm age (*Startup*), which is represented by the year of the Firm minus the year of opening plus 1. (2) Firm financing constraints (*Debtr*), expressed by the debt-to-capital ratio. The higher the value is, the stronger the financing constraint is. (3) Firm scale (*Scale*) is represented by logarithmic output value of the firm. (4) Firm profit rate (*Profitr*) is expressed by the ratio of firm profit to firm gross output value.

4.3 Data Sources

Data source from 2000 to 2012. This paper involves three types of database, which are China Industrial Firms Database, China Firms Pollution Database, and UIBE Database.

4.4 Benchmark Test

The GVC participation degree and length are substituted into the benchmark regression equation for testing. The results of the impact of GVC participation on firm environmental pollution (e.g., Table 1. Benchmark Test).

The first two columns are the estimated results of the influence of GVC length on firm environmental pollution. Column (1) studies the influence of forward-linkage GVC length; Column (2) studies the influence of backward-linkage GVC length; the regression results show that the estimation coefficient of GVC length on firm pollution emission intensity is significantly positive regardless of forward-linkage perspective or backward-linkage perspective, indicating that the extension of GVC length is beneficial to firm emission reduction. Further comparison of the influence of forward-linkage length and backward-linkage length on firm pollution emission intensity shows that extending backward-linkage length has a more significant effect on pollution reduction. on one hand, GVC provides supervision and technical support to firms in developing countries through green, environmental protection and high-quality standards, while firms in developing countries actively play the learning effect. The accumulation of capital and technology keeps increasing, and firms gain more space for process upgrading and product upgrading, which promotes the continuous extension of backward-linkage length, and reduces environmental pollution; On the other hand, when firms in developing countries transform from the stage of process upgrading and product upgrading to the stage of function upgrading and chain upgrading, and transition from the role of "value input" to "value output" in the division of GVC, the forward-linkage length will increase accordingly, which will challenge and threaten the monopoly power of the dominant value chain. The GVC leader will prevent these firms from upgrading their functions and chains by means of technical barriers and so

on, forcing firms in developing countries to lock in the low-end GVC with low added value and high pollution (Humphrey and Schmitz, 2010), thus inhibiting the pollution reduction effect of forward-linkage length. The phased strategy of GVC leaders means that firms in developing countries will reduce pollution based on the extension of GVC participation length, but its role will be constantly weakened.

The last two columns are the estimated results of GVC participation on firm environmental pollution. Column (3) studies the influence of degree of forward participation; Column (4) studies the influence of degree of backward participation; the regression results show that the estimation coefficient of GVC participation on firm pollution emission intensity is significantly positive regardless of the forward participation or backward participation, reflecting that increased degree of GVC participation worsens firm pollution.

Table 1. Benchmark Test

	(1)	(2)	(3)	(4)
PLv_GVC	-0.024**			
	(-2.36)			
PLy_GVC		-0.195***		
		(-13.86)		
Pat_f			0.249***	
			(13.70)	
Pat_b				0.293***
				(10.75)
Profitr	0.001	0.001	0.001	0.001
	(0.89)	(0.89)	(0.78)	(0.77)
Scale	0.077***	0.090***	-0.029***	-0.030***
	(24.12)	(27.72)	(-5.83)	(-6.22)
T_1	0.123***	0.138***	0.018**	0.028***
	(20.91)	(23.31)	(2.21)	(3.45)
T_2	-0.385***	-0.375***	-0.170***	-0.163***
	(-49.28)	(-48.28)	(-11.41)	(-10.68)
Startup	0.008***	0.007***	0.0001	0.001
	(17.15)	(16.16)	(0.74)	(0.84)
Debtr	0.0001	0.0002	-0.0001	-0.0003
	(0.57)	(0.56)	(-0.587)	(-0.622)
City	0.003	0.003	0.062	0.04
	(0.12)	(0.11)	(1.31)	(0.86)
N	472738	472738	325796	325796
R^2	0.01	0.01	0.001	0.001

4.5 Endogenous Analysis

Although benchmark test in control of the firm and year fixed effects, and can better avoid missing problems of the endogenous variable, but due to the core explain variables based on firm level, could be explained with variable firm pollution emissions intensity of reverse causation resulting in endogenous problems. In order to reduce the errors caused by endogeneity problems, this part adopts instrumental variable method (IV) to solve the possible endogeneity of GVC participation degree and length as much as possible.

In this paper, lag time of GVC participation degree and length were selected as instrumental variables respectively. The results show that after considering endogenous (e.g., Table 2. Endogenous Test), GVC length is still significantly negatively correlated with firm pollution emission intensity. Meanwhile, GVC participation and firm pollution emissions intensity is still significant positive correlation, consistent with benchmark results. At the same time, the results show that the estimated coefficient is higher than the benchmark coefficient, which has two implications: on the one hand, the possible endogeneity underestimates the effect of GVC participation on firm pollution reduction; On the other hand, GVC participation has significant lag effect on firm pollution reduction.

Table 2. Endogenous Test

	(1)	(2)	(3)	(4)
LPLv	-0.137***			
	(-9.99)			
LPLy		-0.489***		
		(-22.48)		
LGVC_Pat_f			0.226***	
			(13.16)	
LGVC_Pat_b				0.562***
				(22.19)
Control variables	YES	YES	YES	YES
Fixed effects	YES	YES	YES	YES
N	329248	329248	325796	325796
R2	0.007	0.009	0.001	0.003

4.6 Heterogeneity Analysis

The samples of firms with different characteristics are mixed together to

investigate the average impact effect of GVC participating on firm pollution reduction, without distinguishing different characteristics. This part will further explore whether the core hypothesis of this paper is valid for sectors with different densities and firms with different ownership types.

4.6.1 Different intensity sectors

According to the number of firms in the same industry, the total sample is divided into two types of sectors: high-intensity industry and low-intensity industry. The estimation results (e.g., Table 3. Heterogeneity Test(I))show that the core conclusions of this paper that lengthening GVC participation length helps firms to reduce pollution and increasing GVC participation degree can inhibit pollution reduction are generally robust to different intensity sectors. Further comparison of two type shows that both GVC participation length and GVC participation degree have a more significant effect on the pollution emission intensity in high-density industries, reflecting that the environmental effect of GVC participation is more significant in high-density industries.

Table 3. Heterogeneity Test (I)

	Low-intensity industries		*High-intensity industries*	
PL_GVC	*-0.058***		*-0.334***	
	(-3.56)		*(-12.65)*	
GVC_Pat		*0.019*		*0.915***
		(0.83)		*(20.32)*
Control variables	*YES*	*YES*	*YES*	*YES*
Fixed effects	*YES*	*YES*	*YES*	*YES*
N	*241489*	*157945*	*231249*	*167851*
R^2	*0.011*	*0*	*0.01*	*0.005*

4.6.2 Different types firm

According to the paid-in capital of firms, the total sample is divided into two types of firms: state-owned firms and non-state-owned firms. The estimation results (e.g., Table 4. Heterogeneity Test (II)) show that the estimated coefficients of GVC participation degree and GVC participation length on firm pollution emission intensity in the two types are consistent with the benchmark regression results.

Table 4. Heterogeneity Test (II)

	Non-state-owned firm		*State-owned firms (soes)*	
PL_GVC	-0.123***		-0.575***	
	(-8.02)		(-13.64)	
GVC_Pat		0.297***		0.126***
		(13.75)		(3.34)
Control variables	YES	YES	YES	YES
Fixed effects	YES	YES	YES	YES
N	72120	279896	72120	279896
R^2	0.026	0.002	0.029	0.001

The result means that the core conclusion of this paper is generally robust to firms of different ownership types. Further comparison shows that the regression coefficient of GVC participation degree is more significant in non-state-owned firms, while the regression coefficient of GVC participation length is more significant in state-owned firms. It means that the environmental effect of GVC participation degree is mainly caused by non-state-owned firms, while the environmental effect of GVC participation length is mainly caused by state-owned firms.

5. Conclusions and Suggestions

The conclusions of this paper have important policy implications.First, this paper finds that increasing the degree of GVC participation has a negative "catalyst" effect on environmental pollution while prolonging the length of GVC participation has a significant positive "inhibitor" effect on environmental pollution. Therefore, the state should attach importance to the strategy of prolonging the length of GVC, and achieve a win-win situation between prolonging the length of GVC and green development by enhancing the R&D capability of enterprises. Therefore, the state should extend the GVC length on the one hand, pay attention to the GVC participation model on the other hand, and seek an effective balance between pollution prevention and GVC participation mode through reasonable mechanism design. This study provides a new idea for firm pollution reduction. Environmental pollution can be improved by changing the GVC participation mode, and finally, achieving win-win development of

economy and environment.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Disclosure

Any remaining errors in the paper are the responsibility of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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