Research on the Impact of Global Value Chain Embedding on the Green Development of China's Manufacturing Industry under the Background of Digitalization

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Abstract. This article calculates the green development index of manufacturing industries in China from 2003 to 2020 by constructing the index system for evaluating green development. Based on the input-output table data of OECD database, it obtains the GVC status index and digital input of China manufacturing industries. On this basis, the effect and path of GVC embedding on the green development of manufacturing industry are analyzed experimentally, and the regulatory role of digital economy is analyzed. Finally, the industry heterogeneity is verified. It is found that there is an "inverted U" trend between GVC embedding and the green development of China's manufacturing industry. The rising of value chain can promote the green development, and the promotion effect will gradually weaken with the rise of GVC's status. GVC embedding can promote the green development of manufacturing industry by attracting more FDI and promoting enterprises to increase R&D investment, and the digitalization has a positive regulatory effect on the influence of value chain embedding on green development; and GVC embedding can significantly promote the green development of technology-intensive and labor-intensive industries.

Keywords: Global value chain embedding; Green development of manufacturing industry; Digitization

1 INTRODUCTION AND LITERATURE REVIEW

China has seen significant advancements in its manufacturing sector since the reform and opening up. In 2022, the scale of manufacturing industry remained the first in the world for 13 consecutive years. Although China is a big manufacturing country, there is still a significant gap between it and the world advanced level in terms of independent innovation capability and informatization level. In the early stage of economic construction, the manufacturing sector was at the bottom of the global value chain. With the rapid economic development, it also faced more and more serious resource and environmental pollution constraints. At present, China's manufacturing sector has to abandon the "factor-driven" paradigm immediately. A fresh wave of industrial and technical

R. Magdalena et al. (eds.), *Proceedings of the 2024 9th International Conference on Social Sciences and Economic Development (ICSSED 2024)*, Advances in Economics, Business and Management Research 289,
https://doi.org/10.2991/978-94-6463-459-4_75

revolutions encourages the reconstruction of the global value chain, which creates chances for China's manufacturing sector's green development [1]. With the rapid development of digital economy, accelerated technology diffusion and resource flow, and contributed to the green development of China [2].

The existing literature mainly focuses on the effect of GVC embedding on green development, and analyzes the mechanism of GVC embedding on green development from the theoretical level, lacking empirical research and the role of digital economy in it. And they mainly study the influence of GVC embedding on green development from the embedding position [3] and embedding degree [4]. In addition, regarding the measurement of green development, scholars at home and abroad measure it through efficiency measurement [5] and construction of evaluation index system [6].

On the basis of the above literature, the contribution of this paper may be as follows: (1) Based on OECD database, this paper obtains the GVC position index of China manufacturing industry and the digital input. (2) This paper calculates the green development index of manufacturing industry by constructing the green development evaluation index system. (3) An empirical examination of the mechanism and impact of GVC embedding on the green development of manufacturing industry, verification of the regulatory role of digital economy.

2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

2.1 GVC embedding and green development of manufacturing industry

Now, the research on the influence of GVC embedding on green development can be basically divided into three categories: first, GVC embedding can promote the green development of developing countries; Second, GVC embedding will inhibit the industrial green development of countries at the lower reaches of the value chain[7]; Third, there is not a simple linear relationship between GVC embedding and green development. On the one hand, enterprises at the high end of the value chain have technology spillover effect in the embedding process, which is helpful to the technological innovation of manufacturing enterprises and promotes green development [8]; On the other hand, with the deepening of embeddedness, enterprises at the high end of the value chain will lock in technology, which will make China fall into the "low-end capture trap". In light of the study above, hypothesis 1 is presented.

Hypothesis 1: the influence of GVC embedding on the green development of China's manufacturing sectors shows an "inverted U" trend.

China mainly relies on cheap labor and abundant resources to participate in the global value chain. With the deepening of embedding GVC, China is also improving the standards of environmental regulation. However, it will increase the expenditure on environmental control, crowd out investment in other activities and inhibit the green development; On the other hand, appropriate environmental regulation can encourage

companies to innovate in technology in order to meet environmental regulation standards, resulting in "innovation compensation effect" [9]. Therefore, hypothesis 2 is laid out in this article.

Hypothesis 2: GVC embedding affects the green development of China's manufacturing industry through environmental regulation.

The embedding degree of global value chain is directly proportional to the amount of foreign direct investment, and the quality of FDI will also have an important impact on green development. On the one hand, FDI inflow can bring advanced production technology and management experience to the inflow countries, promote productivity growth, and promote green development; However, the inflow of FDI will also make the inflow countries become pollution shelters, pollute the environment of the inflow countries . Therefore, this paper puts forward hypothesis 3.

Hypothesis 3: GVC embedding affects the green development of China's manufacturing industry through FDI.

China's embedding GVC has deepened the fierce market competition, forcing enterprises to increase R&D investment, increase their capacity for technical innovation and their level of competitiveness, thus promoting green development. First of all, technological innovation can promote industrial upgrading by improving production technology and resource utilization [10], but there is a process of absorption and transformation from increasing R&D investment to innovation to final production [11]. Therefore, this paper puts forward hypothesis 4.

Hypothesis 4: GVC embedding affects the green development of China's manufacturing industry through R&D investment.

2.2 The regulatory role of digitalization in green development

Digitalization of manufacturing industry can optimize the technology spillover effect and connection effect of GVC, promote green development. The digital economy runs through the trade intermediate and final products in the value chain, which can reduce the trade cost, and the penetration of digital economy can accelerate the structural upgrading of human capital, thus the promotion of the division of labor status in the value chain; The new development pattern of "double circulation" provides an opportunity for the development of digital economy, and it conversely provides impetus for the double circulation pattern. Therefore, this paper puts forward hypothesis 5.

Hypothesis 5: Digitalization has a positive regulatory effect on the influence of GVC embedding on the green development of manufacturing sectors.

3 THE EVALUATION OF GREEN DEVELOPMENT LEVEL OF MANUFACTURING INDUSTRY IN CHINA

3.1 China manufacturing green development evaluation index system

This paper constructs a comprehensive evaluation index system of green development from four dimensions: economic development, energy saving and emission reduction,

technological progress and social welfare, so as to measure the green development of manufacturing industry. See Table 1 for specific indicators.

Table 1. Evaluation index system of green development of manufacturing industry

Primary index	Secondary index	Direction of action
A technological innovation	A1 RD funds	+
	A2 RD personnel full-time equivalent	+
	A3 Number of patent applications	+
	A4 Number of valid invention patents	+
B economic benefits	B1 Total assets	+
	B2 Total profit	+
	B3 Operating cost	-
	B4 main business income	+
C energy saving and emission reduction	C1 energy consumption	-
	C2 chemical oxygen demand discharge	-
	C3 solid waste output	-
	C4 smoke emission	-
	C5 SO2 emission	-
D social welfare	D1 number of enterprise units	+
	D2 Average number of employees per year	+

Source: compiled by the author.

3.2 Measurement of green development level of manufacturing industry in China

Digital processing and evaluation methods

Considering the differences in the classification of manufacturing industries between China's National Economic Industry Classification and OECD database, in order to ensure the consistency and accuracy of the data, this paper unifies the two classification methods and decides to classify China's manufacturing industries with OECD database standards. On this basis, referring to Wu Yangwei's (2021) practice [12], some industries were excluded. This article uses entropy method to calculate the green development index of China manufacturing industry.

Evaluation of green development measurement results.

Table 2 is the statistics of the green development index of China's manufacturing sectors from 2003 to 2020. From the table, we can see that the average green development index of C26, C28 and C29-C30 ranked in the top three. These high-tech industries are high in technology content and innovative. C16, C17_18 and C19 are the three industries with the lowest average index of green development.

Table 2. Statistics of Green Development Index of Manufacturing Industry from 2003 to 2020

industry	mean value	Mean ranking	industry	mean value	Mean ranking
C10T12	0.2525	8	C23	0.1951	9
C13T15	0.2555	5	C24	0.2534	7
C16	0.0946	15	C25	0.1687	10
C17_18	0.1210	13	C26	0.4313	1
C19	0.1065	14	C27	0.3161	4
C20	0.2543	6	C28	0.3952	2
C21	0.1562	12	C29-C30	0.3248	3
C22	0.1569	11			

Source: compiled by the author.

4 MODEL SETTING AND DATA

4.1 Model building

The impact of GVC integration on manufacturing industry's green development is the main topic of this research., so the following econometric model is constructed:

$$GDI_{it} = \alpha_1 + \beta_1 GVC_{it} + \beta_2 X_{it} + \varepsilon_{it} \quad (1)$$

Among them, i stands for industry, t stands for time, the explained variable GDI_{it} is the manufacturing sector's green development index, the core explanatory variable GVC_{it} is the position index of global value chain, X_{it} stands for various control variables, and ε_{it} is a random disturbance term.

To confirm whether global value chain embedding and the green development of the manufacturing sectors have a relationship that is not linear, the square term of GVC is added on the basis of formula (1), and the model is set as:

$$GDI_{it} = \alpha_2 + \beta_3 GVC_{it} + \beta_4 GVC_{it}^{\ 2} + \beta_5 X_{it} + \varepsilon_{it} \quad (2)$$

In order to verify the influence mechanism of GVC embedding on the green development of manufacturing sectors, firstly, foreign direct investment (FDI), environmental regulation (ER), R&D investment (RD), GVC are regressed, as shown in formulas (3), (4) and (5). Secondly, check whether the interaction between DIG and GVC has an impact on green development, as shown in Formula (6).

$$LNFDI_{it} = \alpha_3 + \beta_6 GVC_{it} + \beta_7 X_{it} + \varepsilon_{it} \quad (3)$$

$$ER_{it} = \alpha_4 + \beta_8 GVC_{it} + \beta_9 X_{it} + \varepsilon_{it} \quad (4)$$

$$RD_{it} = \alpha_5 + \beta_{10} GVC_{it} + \beta_{11} X_{it} + \varepsilon_{it} \quad (5)$$

$$GDI_{it} = \alpha_6 + \beta_{12} DIG_{it} + \beta_{13} GVC_{it} + \beta_{14} DIG_{it} * GVC_{it} + \beta_{15} X_{it} + \varepsilon_{it} \quad (6)$$

4.2 Variable setting

Explained variable: manufacturing green development index (GDI) is the green development index calculated above.

The core explanatory variable: Global Value Chain Embedding (GVC). In this paper, the GVC position index, which is an index proposed by Koopman et al.(2010) [13].

$$\text{GVC} - \text{position}_{ir} = ln\left(1 + \frac{\text{IV}_{ir}}{E_{ir}}\right) - ln\left(1 + \frac{\text{FV}_{ir}}{E_{ir}}\right) \quad (7)$$

Among them, i stands for industry, r stands for country, and GVC-Position$_{ir}$ stands for the position of industry i in country r in the global value chain; IV$_{ir}$ represents the indirect value-added export of industry i in country r, FV$_{ir}$ represents the value of foreign imported products or intermediate products in the final product export of industry i in country r, and E$_{ri}$ represents the total export calculated by industry i in country r using its added value.

Adjustment variable: Digitization (DIG). Based on He Wenbin's (2021) definition of manufacturing digital input [14], this paper uses the intermediate input value of information industry departments to represent manufacturing digitalization.

Control variables: Foreign direct investment (FDI) is measured by the investment amount from foreign enterprises and enterprises with investment from Hong Kong, Macau, and Taiwan. Environmental regulation(ER) is determined through the calculation of entropy values. Research and development inputs(RD) are measured by the proportion of R&D expenditure to the sales value. Market participation (MD) is measured by the ratio of the number of enterprises in each industry to the total number of enterprises. The structure of energy consumption (ES) is determined by dividing the amount of coal used by all energy used. The energy price is expressed by the purchasing price index of fuel and power industry producers in 2003.

4.3 Data sources

The time span is from 2003 to 2020. The green development index of manufacturing industry is calculated according to the above, the GVC embedding and digitization is calculated according to the OECD database, and the information for the other control variables comes exclusively from China Statistics Yearbook, China Science and Technology Statistics Yearbook and China Environment Statistics Yearbook.

5 EMPIRICAL RESULTS AND ANALYSIS

5.1 Estimation of basic results

This work employs the Hausman test to decide whether to adopt fixed effect or random effect, and ultimately decides on fixed effect in order to prevent the auto-correlation of panel data. Table 3 presents the findings.

Table 3. Regression Results of GVC Embedding and Green Development of China Manufacturing Industry

VARIABLES	Model (1) GDI	Model (2) GDI	Model (3) GDI
GVC	1.234***(4.72)	0.515*(1.73)	
L.GVC			0.826***(3.26)
GVC2		-9.708***(-4.52)	-8.611***(-4.37)
Control variables	YES	YES	YES
Observations	270	270	255
R-squared	0.632	0.660	0.674

Note: The t values of the estimated results are shown in brackets. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

At Table 3, in Model (1), the estimation coefficient of GVC embedding indicates that GVC can promote the green development of manufacturing industry. In model (2), there is an "inverted U" relationship between GVC embedding and green development. The results of model (1) and (2) show that the influence of GVC embedding on the green development of manufacturing sectors is "inverted U". In the process of embedding into global value chain, manufacturing industry can absorb strong knowledge of industrial technology and management, improve productivity and resource utilization efficiency, reduce pollution emissions and promote the green development. However, with the improvement of the status of GVC, enterprises at the upper end of the value chain will lock in the technology, which hinders the technological upgrading of enterprises at the lower end. Thus hypothesis 1 is verified.

5.2 Robustness analysis

It has been verified that the influence of GVC embedding on the green development of manufacturing sectors is "inverted U". In order to further verify the validity of the results, this paper adopts the panel instrumental variable model method to deal with the endogeneity, and takes the core explanatory variable GVC as an instrumental variable, and introduces it into the model. As shown in model (3), the green development index of manufacturing industry shows a trend of promoting first and then inhibiting in the process of integrating into the GVC, and the results of this paper are robust.

5.3 Mechanism analysis

In order to test the influence mechanism of GVC embedding on green development of manufacturing sectors, this article regresses GVC embedding with environmental regulation, FDI and R&D investment respectively. In order to test the moderating effect of digitalization of manufacturing industry on GVC embedding and green development of manufacturing industry, the article introduces the interactive term of GVC and DIG into model (8). Table 4 displays the findings.

Table 4. Mechanism Test of the Impact of Global Value Chain Embedding on Green Development of Manufacturing Industry

VARIABLES	Model (4) ER	Model (5) LNFDI	Model (6) RD	Model (7) GDI
GVC	-0.113(-0.61)	1.992*(1.87)	8.910***(4.34)	0.383*(1.81)
DIG				1.813***(9.92)
GVC*DIG				3.403**(1.98)
Control variables	YES	YES	YES	YES
Observations	270	270	270	270
R-squared	0.370	0.729	0.397	0.798

Note: The t values of the estimated results are shown in brackets. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

In Table 4, the estimation coefficient of GVC in model (4) is not significant. In model (5) and model (6), the regression coefficients of GVC embedding on FDI and R&D investment are both positive, indicating that the rising value chain is conducive to attracting FDI and increasing R&D investment. Combined with models (4)-(6), we can see that FDI and R&D investment are the paths that GVC embedding affects the green development of manufacturing sectors, and hypotheses 3 and 4 are verified.

The coefficient of GVC embedding in model (8) is 0.383, which indicates that global value chain embedding can promote green development, and the coefficient of the cross term between digital input and GVC is 3.403. Through the significance test at 5% level, manufacturing digitalization strengthens the positive impact of GVC embedding on green development. Hypothesis 5 is verified.

5.4 Heterogeneity analysis

This paper classifies manufacturing industries into technology-intensive, labor-intensive and capital-intensive and tests them respectively to investigate whether there is industry heterogeneity in the influence. Table 5 shows the results.

Table 5. Heterogeneity Test of the Impact of Global Value Chain Embedding on Green Development of Manufacturing Industry

VARIABLES	(8) technology-intensive	(9) labor-intensive	(10) capital-intensive
GVC	2.489***(3.24)	0.552**(2.14)	0.222(1.33)
GVC^2	-7.863**(-2.15)	-3.919(-1.54)	-1.079(-0.72)
Control variables	YES	YES	YES
Observations	108	90	72
R-squared	0.831	0.785	0.867

Note: The t values of the estimated results are shown in brackets. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

The results of models (8), (9) and (10) in Table 5 show that technology-intensive and labor-intensive sectors' green development is greatly impacted by GVC embedding, but not on capital-intensive industries. This may be due to insufficient investment in

technology and R&D in capital-intensive industries and foreign blockade. Although the pollution and energy consumption of the industry are relatively low, green development has not been encouraged by the industry's advertising of its GVC status. Therefore, the influence of GVC embedding on the green development of manufacturing industry has certain industry heterogeneity.

6 CONCLUSIONS AND SUGGESTIONS

This article verifies the influence effect and path of GVC embedding on the green development of manufacturing, as well as the adjustment function of digitalization. Finally, it tests the industry heterogeneity. The results show that: (1) The impact of GVC embedding on the green development of China's manufacturing sectors is "inverted U", and moderate integration into the global value chain is helpful to promote the green development, but with the climbing of GVC, the promotion role is decreasing. (2) GVC embedding can indirectly affect the green development of manufacturing industry through FDI and R&D investment. (3) Digitalization of manufacturing industry can play a positive regulatory role in the influence of GVC embedding on the green development of manufacturing industry. (4) GVC embedding contributes favorably to the advancement of green development of technology-intensive and labor-intensive industries.

Drawing from the aforementioned conclusions, this article proposes the following recommendations: (1) From the industrial level, first of all, manufacturing enterprises should introduce new technologies and equipment to improve production efficiency and product quality. Second, strengthen R&D and innovation, develop core technologies and products with independent intellectual property rights. Finally, leverage cutting-edge technology like artificial intelligence to further the digital transformation. (2) From the perspective of government: the government should play its leading role and introduce a series of green industry policies to encourage enterprises to adopt environmental protection technologies and production methods. When formulating industrial policies, it is necessary to fully consider the characteristics of different industries and formulate targeted policies. Besides, the government should increase support for the research, development and application of green technologies, and promote the technological upgrading and green transformation of manufacturing industry.

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