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International Industrial Transfer, Green Technological Innovation, and Manufacturing Global Value Chain Status

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Abstract: Most of the existing literature focuses on how international industrial transfer (IIT) impacts the global value chain (GVC) status of the manufacturing industry from the perspective of narrowly defined FDI but ignores the objective fact that FDI and IIT are not equivalent. Based on theory analysis, we used the TiVA database, the input–output model, and global value chain-related methods to effectively measure the scale of generalized IIT and GVCs of manufacturing sectors in China from 1995 to 2018. On this basis, the relationship between IIT and the GVCs of manufacturing industries and the moderating effect of green technological innovation (GTI) were empirically investigated using industry panel data. The results show that (1) there is a nonlinear inverted U-shaped relationship between IIT and manufacturing GVCs; that is, a larger IIT scale is not better from the perspective of manufacturing GVCs. (2) GTI weakens the inverted U-shaped relationship between IIT and manufacturing GVCs. (3) The heterogeneity analysis found that both medium- and high-technology manufacturing IITs have a nonlinear inverted U-shaped relationship with GVCs, which does not exist in low-technology manufacturing IIT. (4) The benchmark regression results remain robust after replacing the GVC measure, excluding special years and endogeneity treatment and replacing the estimation method robustness test. The research in this paper has implications for optimizing the design of IIT policies to promote the upgrading of manufacturing GVC status.

Keywords: international industrial transfer; global value chain status; manufacturing industry; green technological innovation

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1. Introduction

Academics generally agree that four large-scale international industrial transfers have occurred worldwide, and the main manifestations of the first three international industrial transfers are inter-industry and intra-industry transfers. The types of transfers are mainly in labor- and capital-intensive industries, resulting in the flying geese formation model [1], product life cycle [2], marginal industrial transfer [3], and other theories, which better explain the phenomenon of vertical and horizontal IIT. The fourth IIT began in the 1980s, and the object of IIT shifted from a complete product value chain to a process-based value chain, which is fundamentally different from the industrial transfer based on the inter-industry and intra-industry division of labor and is mainly linked to the by-product value chain [4]. Developed countries that master the production links of key technologies, sales, and core components dominate the value chain and carry out global production based on factor endowments in other production links. However, developing countries primarily involved in low-end process assembly are subordinated in the global value chain (GVC). After the reform and opening up, benefiting from the rapid development of the GVC, China's manufacturing industry has had historic opportunities. Through the advantages of production cost, policy, and market, China actively undertook IIT and rapidly integrated into the global market. The development of the manufacturing industry has made great progress, and China has become the world factory of the manufacturing industry. However, the achievements made by China's manufacturing industry are mainly in the expansion of quantity and scale, and the objective fact that the manufacturing industry centers on the middle and low end of the GVC remains unchanged. To this end, the 19th Party Congress report points out the strategic goal of "promoting China's industry to the middle and high end of the global value chain" [5].

The report of the 20th Party Congress in 2022 pointed out that "We will improve the quality and level of the international circulation, and to guarantee the supply resilience and security level of the industrial chain; we must adhere to science and technology as the first productive force and innovation as the first driving force, accelerate the self-reliance of science and technology, promote basic research and original innovation, and enter the ranks of innovative countries". It can be seen that this is an important assertion and strategic deployment made by the country based on the existing national and world conditions, elevating the upgrading status of the global value chain and scientific and technological innovation to a strategic level. At the same time, to cope with a series of economic and social problems caused by the hollowing out of the manufacturing industry, developed economies have introduced manufacturing backflow policies to regain dominance in the field of manufacturing. At the same time, with the cost dividend and low-cost comparative advantage derived from technological innovation, developed countries have promoted the backflow of the manufacturing industry and the transfer to Southeast Asia, Africa, and other regions [6]. At present, when China participates in the GVC, it will face a dilemma, namely, the issue of "high-end back flow" in developed countries and the competition of "low-end diversion" in other developing countries [7]. It is generally believed that continuous technological innovation is an important path to promote the upgrading of the manufacturing industry [8]. However, traditional technological innovation fails to reflect the environment [9]. The concept of protection cannot meet the needs of sustainable economic development. Therefore, as a dual advantage of environmental protection and economic development, whether GTI can promote the upgrading of China's manufacturing global value chain has received extensive attention and discussion.

Although the fifth international industrial transfer has not been clearly defined in academic circles, the importance of China in this international industrial transfer is an indisputable fact. China is still one of the important undertaking countries of international industrial transfer. Since the 1990s, FDI inflow has been the first in developing countries. Even in 2020, when global FDI declined sharply, China's FDI investment volume still reached USD 144.369 billion, slightly lower than that of the United States, and ranked second in the world for four consecutive years. In this context, a topic with important theoretical and practical significance is derived: How does IIT affect China's manufacturing GVCs? Can it achieve the upgrading of manufacturing GVC status? What role will GTI play in the influence of international industrial input and international industrial output? This article discusses the above questions, which are of great significance for China's industrial policy formulation and upgrading of manufacturing GVCs.

Therefore, in this research, we used the TiVA database, the input–output model, and global value chain-related methods to effectively measure the scale of generalized IIT and GVCs of manufacturing sectors in China from 1995 to 2018. Secondly, the relationship between IIT and the GVCs of manufacturing industries and the moderating effects of green technology innovation were empirically investigated using industry panel data. Therefore, this paper's marginal contributions differ from previous studies and are as follows: (1) This paper not only measures the scale of IIT based on the input–output model, but also measures the scale of final product and intermediate product transfer, which enriches the research on IIT. (2) Unlike the existing literature that mainly regards FDI as an IIT in a narrow sense, this paper takes the perspective of IIT in a broad sense as the entry point and explores the nonlinear relationship between IIT and GVCs. (3) Based on the heterogeneity analysis of the type and technical content of international industrial transfer, this paper discusses the different influences of international industrial transfer on the GVCs.

2. Literature Review

The related literature mainly consists of two types. The first is research related to international industrial transfer, which mainly includes the definition and measurement of international industrial transfer; the second category relates to the GVC, which mainly refers to the measurement and the influencing factors of manufacturing GVCs.

2.1. Measurement of IIT

In the research on international industrial transfer, no consensus has been reached in the academic community on the definition of industrial transfer, but Chen's (2002) [10] definition of industrial transfer has been widely recognized domestically, which is defined as the economic behavior of industry transfer from one country or region to another, including both international industrial transfer and domestic inter-regional industrial transfer, and combined with the micro-enterprise data of Zhejiang Province to verify. This coincides with the idea of foreign industrial transfer measurement. Brouwer et al. [11] and Savona and Schiattarella [12] studied how international industrial transfer affects Italian industrial linkages based on enterprise location information and registration changes. Although the change in enterprise location information can accurately measure the number and scale of industrial transfer, it has high requirements for enterprise information statistics. Due to the general inadequacy of enterprise location information in developing countries, there are great limitations in its promotion.

Thus, more and more scholars have used FDI as a proxy variable for industrial transfer. The study found that foreign direct investment has positive effects such as industrial structure optimization and upgrading [13], knowledge spillover [14], technological innovation [15], and technology spillover [16]. There are also negative effects such as industrial hollowing out [17], environmental pollution [18], and wage gaps [19]. However, FDI can only characterize international industrial transfer in a narrow sense, so some scholars began to use location entropy [12], absolute share index [20], Herfindahl index [21], and industrial gradient coefficient [22] to study the direction and change ratio of industrial transfer. However, the above methods also have some limitations, and it is difficult to measure the scale of international industrial transfer in quantitative terms. Zhang and Liu (2009) [23] extended the existing inter-product industrial transfer to intra-product industrial transfer, focusing on the change in spatial distribution of specific processes, and the form of industrial transfer has changed. Therefore, the applicability of the above methods is generally limited. The input–output model can effectively screen intermediate input and end-use production relationships. Liu, H et al. (2011) [24] first used the input–output model to quantitatively measure the scale and transfer characteristics of industrial transfer in different regions of China from 1997 to 2007, and classified industrial transfer into two types of final demand and intermediate use according to the motives. Wang and Wu (2017) [25] extended this idea to the study of international industrial transfer measurement and measured the scale of industrial transfer of manufacturing and service industries in 22 countries from 1995 to 2011 based on the TiVA database. Undoubtedly, the input–output model provides a new perspective for future research in the field of industrial transfer.

2.2. Research on GVCs

In terms of the GVC, the measurement methods of its related indicators are relatively mature. Hummels et al. (2001) [26] first proposed the vertical specialization level and index (HIY method), where the greater the proportion of intermediate product exports, the higher the division of GVCs. Schott (2004) [27] used the export product price index to measure the GVC; usually, the higher the price of export products, the higher the GVC. Michael (1984) [28] constructed the complexity of export technology, which was continuously revised and improved by scholars [29,30]. The status of the GVC can be measured from three levels: country, industry, and enterprise. Generally speaking, these levels correspond to the technological complexity of exports, the greater competitiveness of products, and the higher position of the value chain. Koopman et al. (2008, 2010, 2012) [31–33], based on the input–output method, integrated Hummels et al.'s (2001) [26] vertical specialization thought, proposed the KWW method that decomposes the total exports into nine items, and proposed the value chain status measurement formula, which is widely used by scholars to study value chain upgrading. Wang et al. (2015) [34] expanded the KWW method, expanding the total exports from 9 decompositions to 16 and decomposing the sector level into reality, calling this the KWWZ method. The continuous progress and improvement of the measurement methods have laid the foundation for GVC-related research.

Scholars have conducted a lot of research on the influencing factors of manufacturing GVCs. According to the existing literature, the influencing factors can be divided into two categories. First, from the point of factor endowment, the development of the manufacturing industry is inseparable from the input of labor, capital, and technology. The second category includes other perspectives such as institutional quality, environmental regulation, FTAs, etc. [35]. From the factor endowment perspective, Lee and Yi (2018) [36] empirically studied the impact of the "talent dividend" on the upgrading of China's manufacturing GVC and found that there is a nonlinear inverted U-shaped relationship between talent factors and the rise of manufacturing GVCs. Liu et al. (2017) [37] empirically examined the role of factor endowments in manufacturing industry upgrading using WIOD and the Chinese Industrial Enterprise Database. The results showed that labor input and human capital accumulation were the main factors affecting industrial upgrading. Technological progress is the intrinsic motivation for latecomer participating countries to break through the "low-end lock-in" of the GVC and realize the upgrading of GVCs. Some scholars examined the impact of intermediate product innovation, technological innovation, and green R&D investment on the upgrading of the GVCs in China's manufacturing industry [38–40]. From the perspective of non-factor endowments, scholars have studied the impact of institutional quality [41], environmental regulation [42], trade policy [43], FTA [44], and digital economy [45] on the upgrading status of manufacturing GVCs.

At present, many scholars have found that the existing research on IIT and the rise of GVC mainly focuses on the influence of FDI. However, FDI and IIT are not equivalent, so such an approach cannot truly reflect the relationship between IIT and GVCs, nor can it portray the impact of final product transfer and intermediate product transfer on GVCs. This paper tries to make contributions to the research in the following areas. First, in terms of data measurement, different from the previous research on IIT, which regards FDI as a proxy variable for IIT, this paper not only measures the scale of IIT based on the input–output model but also measures the scale of final product and intermediate product transfer, which enriches the research on IIT. Secondly, in terms of research perspective, unlike the existing literature that mainly regards FDI as an IIT in a narrow sense, this paper takes the perspective of IIT in a broad sense as the entry point and explores the nonlinear relationship between IIT and GVCs based on the TiVA database (1995–2018) of the Organization for Economic Cooperation and Development (OECD) in 2021, which expands and enriches the IIT and GVC research. Thirdly, in terms of extended analysis, this paper introduces the interaction between GVC participation and IIT, and analyzes the impact of the IIT on the status of the manufacturing GVC under different GVC participation. The IIT is divided into two types: final product transfer and intermediate product transfer. According to the different technical levels, the manufacturing industry is subdivided into low technology, medium technology, and high technology, and then the possible heterogeneous effects of IIT are measured and tested.

3. Theoretical Analysis

3.1. Theoretical Analysis of the Role of IIT in Manufacturing GVCs

The existing literature rarely studies the impact of IIT on GVC upgrading directly but pays more attention to how FDI affects factors related to GVC upgrading, including both positive and negative impacts. In summary, the first factor is technology, including both production technology level and human capital. Breaking through the technical bottleneck can enable firms to ascend the GVCs, as the higher tiers of the GVC usually require high technical capabilities. Some scholars conclude that FDI plays an important role in improving the technical level through the demonstration effect, competition effect, learning effect, and forward–backward correlation effect [46,47]. Financing constraints are the second factor. FDI can help enterprises to overcome financing constraints and thus promote the upgrading of the GVC through capital investment. Poncet and Steingress (2010) [48] used Chinese firm data to find that non-state-owned firms can ease their financing constraints and credit discrimination through FDI. Luo and Chen (2011) [49] found that FDI can not only directly alleviate financing constraints by bringing capital inflows, but also may indirectly alleviate financing constraints by reducing the information asymmetry between enterprises and banks and guiding capital flows to FDI-related enterprises. On the one hand, alleviating financing constraints is beneficial to improving the probability of corporate exports [50] and to increase firm productivity on the other hand [51], both of which are beneficial to upgrade the GVCs. Product quality is the third factor. Humphrey and Schmitz (2002) [52] point out that product quality upgrading which can be improved by FDI is embedded in a form of value chain upgrading.

Of course, the impact of FDI on GVC upgrading may not always be positive, mainly in the following aspects. First, in terms of technical factors, whether there is a technology spillover effect of FDI is still open to debate, as demonstrated by Aitken and Harrison [53] using data from Venezuela, which showed that FDI harms technology spillover. In the early stage of industrial development, due to the wide gap in technology, multinational companies often “induce” local manufacturing firms to import advanced technologies instead of independent R&D by raising the technological standards of intermediate inputs, while they control the high end of the value chain and strategic core links [54,55], which hinders the upgrading of the GVCs of the host country’s manufacturing industry. Second, in terms of the product quality enhancement effect, the entry of foreign firms will intensify industry competition, continuously erode the market share of domestic manufacturing firms through price and quality competition, reduce the market size of local manufacturing firms, and even squeeze local manufacturing enterprises out of the market, generating the FDI capture effect [52]. Third, the entry of MNCs may also solidify China at the “low end of the value chain” [56]. For one thing, export firms may be locked in the OEM production mode, which inhibits their technological progress and value chain upgrading; for another, in the process of value chain upgrading, it may be doubly hindered and blocked by large international buyers or MNCs, which is detrimental to value chain upgrading.

To summarize, in the initial stage of participating in the GVC, China can enjoy the cost advantage and opportunities to learn the technology of developed countries brought by participating in value chains, while the obstacles from developed countries are smaller, which helps its value-added capacity to improve. When the position of the GVCs climbs to a certain height, facing the obstacles and captures of developed countries, due to its lack of competitive advantage and ability to integrate the GVC, it is easy for China to solidify in the “low-end link” of the value chain [57], which is detrimental to the rise of GVCs. So, this paper proposes the following hypothesis:

Hypothesis 1. *A nonlinear inverted “U” relationship exists between international IIT and GVCs.*

3.2. Theoretical Analysis of the Moderating Effect of Green Technology Innovation on IIT and Manufacturing GVCs

The literature has affirmed the positive mechanism of GTI in the upgrading of GVCs. At the early stage of industrial development, late-developing countries start from the specialization stage, gradually build up the initial technical base and production capacity by introducing mature technology and production equipment, and carry out imitative innovation with the technological spillover effect of imports and two-way foreign investment [58,59]. The industry should focus on process upgrading rather than product upgrading, and even a certain degree of functional upgrading [9]. From the perspective of GTI, Humphrey and Schmitz (2002) [52] argue that the path of GVC upgrading in developing countries has three points. First, GTI is the endogenous driving force of GVC upgrading, which can significantly promote economic growth. A country's independent innovation can significantly improve the efficiency of manufacturing labor production, enhance comparative advantage, improve product competitiveness, and achieve product upgrading [60]. Certain comparative advantages also help enterprises to engage in the production of high-value-added products and realize the upgrading of the GVC. Second, a country's independent innovation can promote the improvement of the original production process and the development of new products, reduce the cost of enterprises, increase excess profits, realize the upgrading of manufacturing functions, stimulate the scale effect, and realize the manufacturing value chain leap [61]. Finally, the continuous upgrading of technology can enhance the competitiveness of manufacturing products to a greater extent, expand market demand and exports, and then actively integrate into the GVC to realize a leap from the low end to the high end [62], and finally realize the GVC upgrade of manufacturing products.

The increase in Chinese manufacturing GVCs will challenge the GVCs as well as the interests of the leading enterprises. In this way, the leading enterprises will use various means such as transferring production links to hinder the development of China's manufacturing industry, which in turn hinders the upgrading of China's manufacturing industry GVCs. Under such circumstances, enterprises can only rely on their GTI to break through technical barriers, reduce their dependence on developed countries, and eventually get rid of the control of developed countries [63]. In addition, even without the hindrance of dominant firms, China's manufacturing industry still faces the problem of transforming from low-level (resources and labor, etc.) to high-level (technology and capital, etc.) elements. The competitive advantages as well as integration capabilities of leading enterprises in the value chain are derived from advanced elements, and GTI contributes to the cultivation of high-level elements [64]. Enterprises can improve existing products or technologies, or develop new products and new technologies to achieve GTI, so that enterprises can not only increase the technological content of low-level factor production, but also research and develop high-level factors, and finally establish a value chain completely dominated by themselves to obtain the largest share of revenue in the value chain. Through GTI, enterprises can not only break through the upgrading lock-in of MNCs, but also contribute to the transformation of low-level and high-level elements and bring competitive advantages and value chain integration capabilities to enterprises [65].

In summary, GTI not only can significantly improve the labor production efficiency of the manufacturing industry, enhance comparative advantages, and boost product competitiveness to realize product upgrading, but can also break through the lock-in of developed countries and cultivate competitive advantage to weaken the negative impact of the IIC on the GVCs. So, this paper proposes the following hypothesis:

Hypothesis 2. *GTI weakens the inverted U-shaped relationship between IIT and GVCs.*

4. Research Design

4.1. International Industrial Transfer Accounting

In the 1930s, the American economist Leontief used the input–output model to study economic problems, and this method has gradually been promoted in the academic community. Isard (1951) [66] went further and extended Leontief's one-country input–output model to a multi-country (IRIO) input–output model. The regional input–output model is shown in Table 1. The input–output model has several advantages in the quantitative analysis of IIT. First, the regional input–output model can effectively reflect the relationship between intermediate inputs and outputs between regions, providing the possibility to measure the number of input changes due to changes in final demand. Second, regional input–output models can reflect not only inter-regional and inter-industry economic linkages, but also analyze intra-regional industrial linkages.

Table 1. Regional input–output table.

Output / Input			Intermediate Use							Final Demand			Total Output
			Country-1			…	Country-m			Country-1	…	Country-m	
			S-1	…	**S-n**	…	**S-1**	…	**S-n**				
Intermediate input	Country-1	Sector-1	x_{11}^{11}	…	x_{1n}^{11}	…	x_{11}^{1m}	…	x_{1n}^{1m}	Y_{1}^{11}	…	Y_{1}^{1m}	X_{1}^{1}
		…	…	…	…	…	…	…	…	…	…	…	…
		Sector-n	x_{n1}^{11}	…	x_{mm}^{11}	…	x_{n1}^{1m}	…	x_{nm}^{1m}	Y_{n}^{11}	…	Y_{n}^{1m}	X_{n}^{1}
	…	…	…	…	…	…	…	…	…	…	…	…	…
	Country-m	Sector-1	x_{11}^{m1}	…	x_{1n}^{m1}	…	x_{11}^{mn}	…	x_{1n}^{mn}	Y_{1}^{m1}	…	Y_{1}^{mn}	X_{1}^{m}
		…	…	…	…	…	…	…	…	…	…	…	…
		Sector-n	x_{n1}^{m1}	…	x_{nn}^{m1}	…	x_{n1}^{mn}	…	x_{nn}^{mn}	Y_{n}^{m1}	…	Y_{n}^{mn}	X_{n}^{m}
Value added			V_{1}^{1}	…	V_{n}^{1}	…	V_{1}^{m}	…	V_{n}^{m}	…			
Total output			X_{1}^{1}	…	X_{n}^{1}	…	X_{1}^{m}	…	X_{n}^{m}	…			

According to the input–output theory, it is known from the row balance relationship:

$$X = AX + Y = (I - A)^{-1}Y \tag{1}$$

where A is the direct consumption coefficient matrix and $(I - A)^{-1}$ is the Leontief inverse matrix, i.e., the complete consumption matrix. The value-added coefficient matrix V is defined as the domestic direct value-added rate vector of $1 \times$ N, which is equal to the unit vector I minus the proportion of all intermediate inputs, and E_m as an N $\times$ 1 export vector.

$$V_m = u(I - \sum_{m \neq n} A_{mn}),\ E_m = \sum_{m \neq n} E_{mn} = \sum_{n} (A_{mn} X_n + Y_{mn}) \tag{2}$$

Drawing on the broad definition of domestic industrial transfer by Liu et al. (2011) [24], the input of IIT is defined as the change in the total output of m countries caused by the increase in final demand in n countries. According to the product flow direction, the E_m in Formula (2) is subdivided into five categories, as shown in Formula (3).

$$E_m = DVA\_FIN + DVA\_INT + DVA\_INTREX + RDV + FVA \tag{3}$$

When measuring the input of international industrial transfer, to ensure the accuracy of the measurement results, the domestic value-added double counting part and the foreign value-added part should be excluded. The international industrial transfer input formula is shown in Formula (4):

$$IIT_m = DVA\_FIN_{\mathrm{m}} + DVA\_INT_{\mathrm{m}} + DVA\_INTREX_{\mathrm{m}} \tag{4}$$

4.2. GVC Status

In the existing studies, scholars mainly use the GVC participation index to measure a country's status in the GVC [26,32,67,68]. Wang et al. (2017a, 2017b) [67,68] expanded the method of Fally (2012) [69] and other scholars on the measurement of production length. They measured the forward and backward production length of a country and defined the GVC as the ratio of the two. This index comprehensively considers the upstream and downstream degree index and the characteristic that the production length will not change with the change in the number of industrial classifications, which better makes up for the shortcomings of the first two GVC status indexes. The specific calculation formula is as follows:

$$GVCP = \frac{plv\_GVC}{ply\_GVC} \tag{5}$$

where *plv_GVC* is the production length calculated based on the forward linkage of industrial linkages; *ply_GVC* is the production length calculated based on the backward linkage of industrial linkages, which indicates the distance between the inputs of other countries and the final products of a country's industrial sector. The quotient of the two is the relative upstream degree index of GVCs.

4.3. Methodology and Data

4.3.1. Model Construction

The benchmark model that affects the manufacturing GVCs was constructed considering IIT as the focus of this paper and the core explanatory variable of the model. To test the impact of the IIT on the manufacturing GVCs, the benchmark model is as follows:

$$GVCPO_{i,t} = \alpha_1 + \beta_1 IIT_{i,t} + \beta_2 IIT^2_{i,t} + \sum \beta_i X_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \quad (6)$$

where subscripts i and t denote manufacturing industry segments and years, respectively; the explanatory variable $GVCS_{it}$ represents the GVC status index of industry i in year t; θ_i denotes the individual fixed effect of the manufacturing industry; μ_t and $\varepsilon_{i,t}$ denote the year fixed effect. The core explanatory variable is the international industrial transfer (IIT), and the squared term of international industry transfer is added to explore the nonlinear relationship of the effect of industry transfer on manufacturing GVC status. $X_{i,t}$ represents other control variables, including capital intensity (Capital), number of employees (Labor), foreign direct investment (FDI), profit level (Profit), and industry size (Size). To further consider the impact of GTI on international industrial transfer and manufacturing GVCs, GTI is added to Formula (6) to obtain Formula (7):

$$GVCS_{i,t} = \alpha_1 + \beta_1 IIT_{i,t} + \beta_2 IIT^2_{i,t} + \beta_3 GT + \sum \beta_i X_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \quad (7)$$

Further, to study the mechanism of IIT in the GVCs of the manufacturing industry, the model of the expanded form is constructed by adding the interaction term of IIT and RD based on Equations (6) and (7), as follows:

$$\begin{aligned} GVCS_{i,t} &= \alpha_1 + \beta_1 IIT_{i,t} + \beta_2 IIT^2_{i,t} + \beta_3 GTI + \lambda_1 IIT \times GTI + \lambda_2 IIT^2 \times GTI \\ &+ \sum \beta_i X_{i,t} + \theta_i + \mu_t + \varepsilon_{i,t} \end{aligned} \quad (8)$$

4.3.2. Control Variable Selection

The model set mainly focuses on the impact of the core explanatory variable IIT on the GVCs of the manufacturing industry, but many factors affect the upgrading of manufacturing GVCs. Based on the existing literature research, five industry characteristic variables were selected in this paper to reduce the impact of omitted variables on the model estimation results.

Industry capital intensity (Capital). Based on factor endowment theory, manufacturing industry segments should be produced based on their factor endowment characteristics. At present, China is in the realistic stage of transformation from labor endowment to capital endowment. Factor endowment has an important impact on the upgrading of the manufacturing industrial structure and the upgrading of GVCs. Based on the calculation method of Tian et al. (2022) [70], the ratio of industry net fixed assets to the number of employees in the industry is used to characterize industry capital intensity.

Industry employees (Labor). Labor input is one of the important bases for the division of manufacturing industries. Based on the calculation method of Jangam and Rath (2020) [71], the average number of employees in the industry is chosen as the metric.

Foreign direct investment (FDI). FDI promotes the international competitiveness of enterprises and enhances the GVC of enterprises through technology spillover effects [72]. Based on the calculation method of Claudio et al. (2022) [73], it is measured by the sum of the total foreign direct investment and Hong Kong, Macao, and Taiwan direct investment.

Profit revenue (Profit). Firms with higher profits will tend to increase R&D investment, update equipment, and introduce talents to strengthen their international competitiveness and optimize their product value chain. Drawing on the calculation method of Ali et al. (2021) [59], the total industry profit is used to measure profit revenue.

Industry size (Size). A larger scale of enterprise output and sales implies a stronger ability to resist risks, and a larger industry size is more conducive to the formation of economies of scale and enhanced international production network linkages. Based on the calculation method of Fang and Gallagher (2016) [39], industry product sales revenue is used to measure industry size.

Green technology innovation (GTI). Green technology innovation refers to the technological innovation that takes ecological economy as the principle, realizes pollution reduction and emission reduction, and weakens the negative externality of the enterprise development process to the ecological environment. Due to the high emissions and high pollution characteristics of resource-based enterprises, pollution reduction and emission reduction are their main tasks. The ratio of R&D investment to three waste emissions is used as a measure of green technology innovation.

4.3.3. Data Source

The measurement of IIT and GVC needs the international input–output table. Currently, the widely used databases are the Asian Development Bank Database (ADB), the World Input-Output Database (WIOD), the Global Supply Chain Database (EPRA), and the Organization for Economic Cooperation and Development Database (OECD-TiVA). The OECD database covers a wide range of time and updates quickly. This paper uses the latest version of the OECD (2021) database to measure the scale of international industrial input and output in the manufacturing industry from 1995 to 2018, as well as the GVC participation index. Since the manufacturing industry in the TiVA database is not consistent with the classification code of the domestic national economic industry (GB/T4754-2011), the method of Wang (2019) [74] was used to match the sub-sectors of the manufacturing industry. The other variables were mainly from the *China Statistical Yearbook* (1995–2019) and *China Industrial Economic Statistical Yearbook* (1995–2019). It should be noted that some statistical data from before 2002 (including) are missing, and the missing data were filled using the interpolation method. Table 2 displays the descriptive statistics of the variables.

Table 2. Statistical description of variables.

Variable	Obs	Mean	S.D.	Min.	Max.	VIF
GVCPO	360	0.8352	0.1845	0.5387	1.3093	-
IIT	360	7.2789	1.4415	4.1677	10.4623	3.68
GTI	360	10.782	4.238	0.001	51.491	1.25
Capital	360	23.3963	27.7769	3.0940	348.6068	2.24
Labor	360	5.19891	0.8288	2.7233	6.7216	1.10
FDI	360	6.9702	1.0852	4.2783	9.0826	4.31
Profit	360	40.4231	50.8579	−228.2495	393.6716	1.84
Size	360	73.4853	85.6453	4.8227	635.0515	2.73

5. Empirical Results

5.1. Benchmark Results

After analyzing the collinearity of panel data, STATA software was used to test the panel data by the Houseman test, and the fixed effects model was chosen for regression. Columns (1)–(4) of Table 3 gradually report the empirical results with the industry effect and time effect controlled.

The results of Column (1) in Table 3 show that the quadratic coefficient of IIT ($\beta = -0.0050$, $t = -5.16$) is significantly negative, indicating that international industrial transfer and GVCs have a nonlinear inverted U-shaped relationship. In the short term, the IIT is conducive to promoting the rise of GVCs, but in the long run, it will cause "low-end locking" of value chain status. Columns (2)–(4) are the results of the impact of the IIT on GVCs after adding industry capital intensity, number of employees in the industry, foreign direct investment, profit level, and industrial scale. After gradually adding control variables, the quadratic coefficient of IIT is still significantly negative, which again verifies the nonlinear inverted U-shaped relationship between international industrial transfer and GVCs. The possible reason is that IIT has both positive and negative effects on the upgrading of GVCs. From the perspective of short-term positive factors, firstly, IIT mainly alleviates financing constraints through capital inflows, thus enhancing the position of enterprises in GVC; secondly, IIT can also promote process upgrading, product upgrading, and chain upgrading through technology spillover effects, and enhance the GVCs. Therefore, in the short term, IIT will help to rapidly improve the capital, technology, and advanced management experience, thus enhancing the GVCs of the manufacturing industry. In the long-term negative impact, the IIT also has the effect of technology "low-end locking", which is locked in a specific production mode and technology path. At the same time, it will also be subject to double blocking and control by the "chain master" countries. The value added that the developing countries create is captured by developed countries rather than by the rise of GVCs. What is worth being vigilant about is if China's manufacturing industry cannot achieve key technological breakthroughs and industrial structure upgrading in the process of value chain upgrading. In this situation, it seems inevitable for China to fall into the trap of comparative advantage and be locked in the low-end production link of the GVC. To summarize, an inverted U-shaped relationship remains between IIT and GVCs, and Hypothesis 1 is verified.

Table 3. Benchmark results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	GVCs	**GVCs**	**GVCs**	**GVCs**	**GVCs**	**GVCs**
IIT	0.0242 (1.54)	0.0219 (1.39)	0.0296 * (1.87)	0.0182 (1.23)	0.0261 * (1.76)	0.1794 *** (3.41)
IIT^2	−0.0050 *** (−5.16)	−0.0048 *** (−4.96)	−0.0049 *** (−4.98)	−0.0038 *** (−4.13)	−0.0042 *** (−4.55)	−0.0153 *** (−3.54)
Capital	-	0.0001 (1.26)	0.0002 ** (2.05)	0.0001 (0.27)	−0.0001 (−0.33)	0.0001 (0.19)
Labor	-	0.0030 (0.82)	0.0035 (0.96)	0.0024 (0.71)	0.0022 (0.67)	0.0022 (0.68)
FDI	-	-	−0.0164 * (−1.77)	−0.0365 *** (−4.04)	−0.0294 *** (−3.18)	−0.0361 *** (−3.55)
Profit	-	-	−0.0001 (−1.60)	−0.0001 *** (−2.90)	−0.0001 *** (−2.67)	−0.0001 ** (−2.17)
Size	-	-	-	0.0003 *** (7.26)	0.0003 *** (5.62)	0.0003 *** (6.06)
GTI	-	-	-	-	0.0185 *** (2.96)	0.0686 ** (2.54)
IIT × GTI	-	-	-	-	-	−0.0274 *** (−3.41)
IIT^2 × GTI	-	-	-	-	-	0.0020 *** (3.27)
Constant	0.6655 *** (10.80)	0.6546 *** (10.19)	0.7133 *** (8.98)	0.8779 *** (11.39)	0.8639 *** (11.53)	0.4403 *** (2.91)
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360
R-squared	0.3209	0.3256	0.3415	0.4359	0.4512	0.4709

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The t values are in parentheses. the same below.

5.2. Moderating Effect

The quadratic term (β = −0.0042, t = −4.55) of the value chain embedding position remains significant when GTI is added to Column (5) of Table 3. To verify the moderating effect of GTI and technology introduction in the relationship between value chain embedding status and value-added ability in Hypothesis 2, the interaction term is added based on Column (5). In Column (6), the coefficient of GTI multiplied by the quadratic term of GVCs is significantly positive (β = 0.0020, t = 3.27), indicating that GTI will weaken the inverted U-shaped effect of IIT on GVCs. This is because GTI will increase the cost of technological catch-up and business risks, which weakens China's low-cost advantage in the early stage of integration into the value chain. However, with the continuous improvement of the embedded position, GTI can break the obstacles of developed countries, complete the transformation from low-level to high-level elements, and form a competitive advantage and value chain integration ability to compete with developed countries. Therefore, GTI weakens the inverted U-shaped relationship between IIT and manufacturing GVC status, and Hypothesis 2 is verified.

5.3. Analysis of Regression Results Based on Industry Grouping

Taking technical heterogeneity in the manufacturing industry into consideration, we further analyzed IIT influence on the GVCs under three types of industries: low-, intermediate-, and high-technology industries. Column (1) in Table 4 is based on the regression estimates of low-tech manufacturing, and Columns (3) and (4) in Table 4 are based on the regression estimates of medium-tech and high-tech manufacturing industries. In the low-tech manufacturing subgroup industries, the coefficient of the international industry quadratic term does not pass the significance test, and IIT has not significantly improved its GVCs. The main reason for this is that since the reform and opening up, China has participated in the GVC with labor-intensive manufacturing, and the industrial structure has been continuously upgraded and optimized. However, with the disappearance of China's demographic dividend and the onset of an aging population, labor factor endowments have gradually been replaced by capital endowments. The IIT is not one of the conditions for low-tech manufacturing to enhance the GVCs. In comparison, in the medium-tech and high-tech manufacturing sub-sectors, the quadratic coefficient of IIT is significantly negative and has passed the statistical significance test. This result shows that for medium- and high-tech manufacturing industries, the IIT has a nonlinear inverted U-shaped relationship with GVCs, which is consistent with the regression results under the full sample conditions. This implies that, except for low-tech manufacturing, there is a "ceiling" effect of IIT on the GVCs of both medium- and high-tech manufacturing industries in the process of upgrading.

Table 4. Regression results based on industry grouping.

Variables	(1)	(2)	(3)
	Low-Tech	**Medium-Tech**	**High-Tech**
IIT	0.0279	0.2043 ***	−0.0048
	(1.28)	(3.91)	(−0.19)
IIT^2	−0.0017	−0.0158 ***	−0.0030 **
	(−0.98)	(−4.65)	(−1.96)
Control variables	Yes	Yes	Yes
Constant	0.3319 **	0.3803 *	1.6091 ***
	(2.41)	(1.89)	(10.11)
Industry fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	96	120	144
R-squared	0.6376	0.6794	0.6952

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The t values are in parentheses.

5.4. Analysis of Regression Results Based on IIT Grouping

The GVC trade can divide export products into final products and intermediate products according to their final use, and IIT can also be divided into final products and intermediate products transfer. The process of IIT generally begins with the transfer of final product production and gradually transitions to the transfer of intermediate product production, and even partial or overall withdrawal from the production process. The key influencing factor is that there is a reasonable technological gradient gap between the exporting country and the importing country. Generally, the production technology content of intermediate products is higher than that of final products. It is foreseeable that the international industrial transfer of different product types will have different impacts on manufacturing GVCs. Column (1) in Table 5 shows the empirical result of the impact of the IIT of final products on the GVCs of the manufacturing industry, which means that an inverted U-shaped relationship remains between them. The reason is that at the initial stage of China's international industrial undertaking, it mainly engaged in assembly, processing, and production, and exports in the form of final products. The most typical cases are the "Barbie doll" and "Apple phone" which require a large number of imported intermediate products, which is conducive to the rapid policy of labor-intensive manufacturing for developing countries. Most trade income is obtained by the upstream link, and the domestic value-added rate is extremely low in developing countries which are susceptible to being "low-end locked" by developed countries.

Table 5. Regression results based on international industrial transfer groupings.

Variables	(1)	(2)
	GVCs	GVCs
IIT-fnl	−0.0159 ** (−2.39)	-
IIT^2-fnl	−0.0028 *** (−5.70)	-
IIT-int	-	0.0180 (1.27)
IIT^2-int	-	−0.0032 *** (−3.46)
Control variables	Yes	Yes
Constant	0.9383 *** (17.04)	0.9055 * (12.83)
Industry fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
Observations	360	360
R-squared	0.4961	0.3949

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The t values are in parentheses.

Column (2) in Table 5 shows the empirical results of the IIT of intermediate products on manufacturing GVCs, indicating that an inverted U-shaped relationship exists between them. The reason is that the IIT of intermediate products means that China can undertake more intermediate products in the international division and increase the value-added ratio in exports, which is beneficial to the upgrading of manufacturing GVCs in the short term. When China's manufacturing GVCs climbs to the high end, it will endanger the GVCs of the upstream countries and is vulnerable to the technological blockade of the upstream countries, thus hindering the GVCs of the manufacturing industry. In contrast, the technical content contained in the intermediate product transfer is higher than that of the final product, so the industrial transfer of the final product is more likely to be controlled by the "chain master" countries, and the inverted U-shaped curve of IIT of final products and the manufacturing GVCs is steeper than that of IIT of intermediate products. In summary, the IIT of both final and intermediate products has an inverted U-shaped relationship with manufacturing GVC status.

5.5. Robustness Tests

We employed four methods to conduct robustness tests: first, replacing the explanatory variables; second, excluding special years; third, endogeneity treatment; and fourth, robustness test of measurement methods.

5.5.1. Robustness Tests for Replacing the Explanatory Variables

Johnson and Noguera (2012) [75] pointed out that the domestic value-added rate index (DVAR) can reflect a country's ability to add value and benefit from participating in the GVC. So, DVAR is used as a proxy variable for the GVCs. In Columns (1)–(2) in

Table 6 show, the regression results with added control variables show that the inverted U-shaped relationship between IIT and manufacturing GVCs is consistent with the benchmark regression results. The quadratic term coefficient and significance level of IIT have not changed compared with the main results. In conclusion, the robustness test based on replacing the explained variables proves that the main regression results are reliable.

Table 6. Robustness test based on replacing explained variables and excluding special years.

Variables	DVAR		GVCs	
	(1)	(2)	(3)	(4)
IIT	0.0319 (1.48)	0.201 *** (4.52)	0.0215 ** (0.82)	0.107 *** (2.92)
IIT^2	−0.0065 *** (−4.89)	−0.019 *** (−4.58)	−0.0032 *** (−3.46)	−0.011 *** (−3.01)
IIT × GTI	-	−0.020 *** (−5.84)	-	−0.012 *** (−4.59)
IIT^2 × GTI	-	0.002 *** (4.52)	-	0.001 *** (2.82)
Control variables	Yes	Yes	Yes	Yes
Constant	1.5084 *** (13.46)	0.159 (1.11)	0.8889 *** (11.29)	0.538 *** (5.92)
Industry fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Observations	360	360	330	330
R-squared	0.5461	0.4380	0.4411	0.4102

Note: **, and *** indicate significance at the 5%, and 1% levels, respectively. The t values are in parentheses.

5.5.2. Robustness Test Excluding Special Years

The sample study period includes two financial crises in 1998 and 2008. To exclude the influence of economic crisis factors on the regression results, this paper excludes the sample data from 1999 and 2009. From Columns (3)–(4) in Table 6, both IIT and output have an inverted U-shaped relationship with manufacturing GVCs and pass the statistical significance test, which further supports the benchmark regression results.

5.5.3. Robustness Test Based on Endogenous Treatment

The previous period's manufacturing GVCs will influence the current period's manufacturing GVCs, and the inevitable effects of omitted variables in the model set will cause possible endogenous problems in the model. Therefore, this paper draws on the instrumental variable selection method of Liu and Han [76] and Xin et al. [77] and adopts two methods of endogeneity testing: one lag of core explanatory variables and one lag of all explanatory variables. The regression results applied to the system GMM method are shown in Columns (1)–(4) of Table 7. The empirical results are consistent with the benchmark regression results, which means that the robustness test based on endogenous treatment once again verifies the high logical consistency of the benchmark regression results.

5.5.4. Robustness Test of Changing Econometric Methods

To re-estimate the model by using maximum likelihood estimation (MLE), generalized least squares (GLS), and robust OLS, the adverse effects of heteroscedasticity and intra-group autocorrelation on the regression model are effectively corrected. The regression results are shown in Columns (1)–(6) of Table 8. Among them, Columns (1), (3), and (5) are the estimation results of the impact of IIT on manufacturing GVCs. The quadratic coefficients of IIT^2 are −0.0038, −0.0034, and −0.0038, all of which are significantly negative and consistent with the benchmark estimation results. Columns (2), (4), and (6) are the estimation results of the impact of IIT on the GVCs of the manufacturing industry. The coefficients of the quadratic term of IIT^2 are significantly negative, which confirms the robustness of the benchmark regression results. The empirical results again verify the robustness of the benchmark results.

Table 7. Endogenous test.

Variables	(1)	(2)	(3)	(4)
	Core Explanatory Variables	**Core Explanatory Variables**	**Explanatory Variables**	**Explanatory Variables**
IIT	0.0336 (1.52)	0.1901 *** (4.12)	0.0179 (0.92)	0.2008 *** (4.52)
IIT^2	−0.0041 ** (−2.34)	−0.0177 *** (−4.15)	−0.0038 ** (−2.48)	−0.0195 *** (−4.58)
IIT × GTI	-	−0.0209 *** (−5.07)	-	−0.0200 *** (−5.84)
IIT^2 × GTI	-	0.0017 ** (4.05)	-	0.0019 *** (4.52)
Control variable	Yes	Yes	Yes	Yes
Constant	0.8439 *** (5.51)	0.1481 (0.91)	0.8753 *** (6.67)	0.1592 (1.11)
Industry fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Observations	360	360	360	360
AR (1)	0.9760	0.0480	0.6940	0.0049
AR (2)	0.2440	0.2024	0.3080	0.1910
Sargan Test	923.07 (0.000)	1017.69 (0.000)	1105.23 (0.000)	1232.22 (0.000)

Note: **, and *** indicate significance at the 5%, and 1% levels, respectively. The t values are in parentheses.

Table 8. Robustness test based on econometric methods.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	MLE		**FGLS**		**ROUBUSTOLS**	
	GVCs	**GVCs**	**GVCs**	**GVCs**	**GVCs**	**GVCs**
IIT	0.0182 (1.31)	0.1791 *** (3.66)	0.0142 (1.08)	0.1984 *** (4.30)	0.0182 (1.21)	0.1791 *** (3.01)
IIT^2	−0.0038 *** (−4.42)	−0.0153 *** (−3.80)	−0.0034 *** (−4.05)	−0.0169 *** (−4.50)	−0.0038 *** (−3.57)	−0.0153 *** (−3.09)
IIT × GTI	-	−0.0274 *** (−3.66)	-	−0.0290 *** (−4.05)	-	−0.0274 *** (−3.16)
IIT^2 × GTI	-	0.0020 *** (3.52)	-	0.0022 *** (4.05)	-	0.0020 *** (2.96)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.8779 *** (12.18)	0.4403 *** (3.13)	0.9042 *** (13.64)	0.4100 *** (3.11)	0.8779 *** (9.41)	0.4403 *** (2.60)
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360
R^2	-	-	-	-	0.9749	0.9765
LR	314.47	337.54	-	-	-	-
Wald	-	-	14,928.97	15,807.74	-	-

Note: *** indicate significance at the 1% levels, respectively. The t values are in parentheses.

6. Conclusions and Implications

In this work, we measured the scale of IIT in China from 1995 to 2018 using the input–output model based on the TiVA database and studied its impact on the upgrading of China's manufacturing GVCs. Furthermore, the moderating effect of GTI on the impact of IIT and the manufacturing GVCs was discussed, and the heterogeneity analysis was carried out based on the technical level and the type of international industrial transfer. The main conclusions are drawn as follows.

(1) There is a nonlinear inverted U-shaped relationship between IIT and manufacturing GVCs; that is, from the perspective of manufacturing GVCs, bigger is not better for the IIT scale.
(2) Green technological innovation plays a significant positive moderating role between IIT and manufacturing GVCs. GTI weakens the inverted U-shaped relationship between IIT and manufacturing GVCs.
(3) The heterogeneity analysis found that the IIT of medium- and high-tech manufacturing industries has a nonlinear inverted U-shaped relationship with the GVCs, and this relationship does not exist in the low-tech manufacturing industries. This implies that, except for low-tech manufacturing, the IIT has a "ceiling" effect on the GVCs of medium- and high-tech manufacturing. The IIT of final products and intermediate products has an inverted U-shaped relationship with the manufacturing GVCs, but the inverted U-shaped curve of the IIT of final products and the manufacturing GVCs is steeper than that of the IIT of intermediate products.
(4) The baseline regression results remained robust after replacing the GVC measurement, excluding special years and endogenous treatment, and replacing the econometric method robustness test.

The possible policy implications of this paper are proposed based on our research.

(1) In the face of the drastic impact of external shocks, such as the decoupling of China and the United States, the new coronavirus epidemic, and the slowdown of global economic growth, China should continue to adhere to opening up, actively undertake international high-tech industry transfer, optimize the industrial structure of manufacturing industry, and enhance the international competitiveness of products. It should also be fully aware of the negative impact of the "low-end locking" that may be brought about by IIT on the manufacturing GVCs. China's manufacturing industry needs to shorten this process by introducing → digesting → absorbing → re-innovating to promote the early arrival of the inflection point and break through the "low-end locking" of the GVC of developed countries, and realize the upgrading of the manufacturing GVCs.
(2) China should use two resources and two markets at home and abroad, strengthen the domestic and foreign industrial linkage, and form a development pattern with domestic circulation as the main linkage and domestic and international circulation as the mutual linkage. On the one hand, China should actively promote the manufacturing industry to use foreign resources and markets through the transfer of gradient industries, reduce production costs, and enhance the international competitiveness of products; on the other hand, China should absorb foreign advanced production technology through reverse-gradient industrial transfer, expand the international cycle, and strive to climb up to the middle and high end of the manufacturing industry.
(3) China should pay attention to the role of GTI, build an endogenous development mechanism of independent innovation, and promote the transformation of the industrial technology innovation mode. The industry should construct the endogenous development mechanism of independent innovation by strengthening scientific research investment with enterprises as the main body of innovation, giving full play to the driving mechanism of enterprise engineering technology research centers; improving the integration mechanism of government, industry, and universities; researching through applications; and cultivating the joint innovation mechanism among enterprises. Based on GTI, China should promote technological progress and provide continuous impetus for enterprise development [78]. Finally, China should change its growth model. The government can support key areas, important links, and key

industries to promote the breakthrough of some common technologies, and thus drive the overall development of the manufacturing industry.

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