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Impact of Embedded Global Value Chain on Technical Complexity of Industry Export—An Empirical Study Based on China's Equipment Manufacturing Industry Panel

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Abstract: This study uses the World Input–Output Database (WIOD) to construct an export technical complexity index based on the effective elimination of imported foreign technology. The panel data of China's equipment manufacturing industry from 2000 to 2014 are used as a sample, and the instrumental variable method is used to test the impact of the embedded global value chain on the technical complexity of industry exports. The impacts of different embedding time periods and different embedding methods on the technical complexity of industry exports are also explored with a view to providing reference recommendations to improve the technical complexity of China's equipment manufacturing exports. The study finds that embedding a global value chain (GVC) can promote the export technical complexity of the equipment manufacturing industry, and with the improvement of domestic openness and industry research and development (R&D) investment conditions, the promotion effect will become increasingly potent. In addition, the backward and forward embedded global value chain (GVC) can promote the export technical complexity of the industry, and the effect of the promotion of backward embedding is even greater.

Keywords: embedded global value chain; export technical complexity; equipment manufacturing industry; industry panel

1. Introduction and Literature Review

Since the 21st century, the specialization of labor division and fragmentation of production have become prominent features of the international economic structure and the global value chain (hereafter referred to as “GVC”), characterized by the division of transnational production, has developed rapidly. Since the comprehensive implementation of its reform and opening-up policy, China has successfully embedded GVCs with its abundant natural resources and the advantages of its labor factors. The development of various industries has quickly been integrated into GVCs, and China has gradually become a “world processing factory.” From 2000 to 2014, China's equipment manufacturing industry has been actively integrated into the GVC production system, and the degree of embedded GVCs has continued to increase. For a long time, China has used processing trade as the main method of growth, relying on low-tech means such as processing and assembly and OEM—i.e., the main way of embedding GVCs has been backward embedding. However, in recent years, China's equipment manufacturing industry has gradually participated in the processing and assembly of some high-end production links, and the international division of labor in China's equipment manufacturing industry has begun to change. The gap between the forward and backward embeddedness of the equipment manufacturing industry has been shrinking year by year. In 2000, the forward and backward

embedding degrees of China's equipment manufacturing industry were 12% and 20.45%, respectively. By 2014, the forward and backward embedding degrees were 16.43% and 19.05%, respectively. At the same time, China's equipment manufacturing industry has continuously improved its production technology level and the industry has made a series of breakthroughs in independent research and development. The manufacturing of complex export technology has increased from 155,700 units in 2000 to 249,500 in 2014. The following questions arise from this: is the rapid increase in export technology complexity of China's equipment manufacturing industry caused by embedded GVC? If so, how does embedding GVCs affect the technical complexity of the industry's exports? Does the embedding of GVCs in different time periods and different embedding methods have the same impact on the technical complexity of the industry's exports?

At present, the impact of embedded global value chains on export technology complexity is mainly concentrated in the manufacturing sector. The Chinese manufacturing industry is actively participating in the global division of labor, and the global value chain is increasingly embedded [1]. At the same time, the technological content of China's manufacturing exports is increasing, and the domestic technological content is growing faster than the overall technological content, which indicates that China's manufacturing industry has been upgraded and optimized to a certain extent [2]. By combing the research on this issue by scholars in recent years, it is found that there are two perspectives regarding the impact of the equipment manufacturing industry's embedded GVC on the export technical complexity: the first is that embedding the GVC can promote the increase of the export technology complexity of the industry and will increase the tendency of technological innovation in manufacturing companies [3]. As an important feature of embedded GVC is the importation of intermediate products, and the middle products are important carriers of technology diffusion [4], importing high-quality intermediate inputs can bring significant reverse technology spillovers to China [5,6]. Similarly, China will also bring technology spillover effects to some countries in the low-end of the global value chain [7]. It was further found that the impact of embedded GVCs on export technology content shows significant industry differences, and the technology promotion effect for capital-intensive industries is greater than the technology promotion effect for labor-intensive industries [8,9], because capital-technology-intensive companies have a stronger learning effect when participating in the global division of labor and have a stronger ability to absorb technology [10]. However, some scholars have pointed out that embedding GVC can inhibit the export technology content of the industry, and they think that the entry of multinational companies will reduce the R&D intensity of domestic companies [11]. For example, Lu Yue, Chen Shuai, and Sheng Bin (2018) found that GVC embedding has a significant negative relationship with R&D willingness and intensity [12]. As China's industries embedded in GVCs are still mainly labor-intensive industries with low added value and low technology content [13], China has long been involved in the GVC, mainly through the processing trade, relying on the advantage of low labor costs, and it mainly participates in the production of low-end links in the value chain with low technical complexity. The long-term foundry environment will strengthen the reliance on low-end factors such as cheap labor, which will gradually strengthen the de-tech trend of local enterprises, especially the mid- and high-tech sectors which are facing the low-end trend of high-end industry development [14,15].

In response to the two different viewpoints above, some scholars have considered the impact of the staged embedding of the GVC on the technical complexity of industrial exports and found that the impact of embedded the GVC on the technical complexity of industrial exports was an inverted "U" shape. When China's embedded GVC reaches a certain "threshold", the push effect will be less than the inhibitory effect [16]. This view was put forward to reappraise and review this research question. However, some people have pointed out that, with the industry's digestion and absorption of imported foreign technology and familiarity with relevant production standards and technological processes, the impact of the embedded GVC on the promotion of the industry's export technical complexity has changed from suppression to promotion [17]. Therefore, the impact of the embedded GVC on the export technical complexity of the industry has a periodical characteristic. When industry

development is focused on product upgrades and process upgrades, embedding the GVC promotes the technical complexity of the industry's export. On the contrary, when industry development is focused on functional upgrades and chain upgrades, embedding the GVC will inhibit the increase in industry export technology complexity [18]. Irrespective of which stage the industry is in, the industry's own domestic financial constraints, the ability to absorb imported technologies, and the domestic environment will all impact the effects of embedding in GVC [19–21]. In addition, improving the production process and organizational management mode will also promote the increase of the export technical content of the industry [22,23].

The uncertain impact of an embedded GVC on the technical complexity of exports is affected not only by industry differences and embedded time period differences but also by embedded feature differences. From the embedded position, the closer to the upstream the position of the embedded GVC, the greater the promotion of export technical complexity [24]. From the perspective of embedded regions, compared with non-OECD economies, Chinese companies embedded in the OECD economy market can actively promote the export technical complexity of resource-intensive industries, but will inhibit the export technical complexity of labor-intensive industries [25]. From the perspective of the embedded path, the embedded path adopted by enterprises to export first and then import has a stronger and longer-lasting effect on the improvement of export technical complexity, because the previous export experience of the company paves the way for the subsequent import of intermediate products. From the perspective of the embedded structure, compared to the embedding of raw materials, parts, and other products, service embedding has a greater effect on improving the export technical complexity of manufacturing exports [26]. There are few studies on the heterogeneity of GVC embedding methods. Wang Siyu and Zheng Lekai (2019) found that the forward embedding of GVCs can further promote the export technical complexity [27].

Generally speaking, the impact of embedded GVCs on the technical complexity of industrial exports is uncertain, because the impact of embedded GVCs on the technical complexity of industrial exports will be affected by factors such as industry heterogeneity, the time phase of the embedded GVC, and differences in embedded features. What is the impact of embedded global value chains on the technical complexity of China's equipment manufacturing exports? Is there heterogeneity in the embedded methods? Therefore, in order to clarify the impact of embedded GVCs on the technical complexity of industry exports, this must be studied in the specific industry development stage and in the context of specific embedded features. In addition, the differential impact of forward and backward embedded GVCs on the technical complexity of the industry's exports needs to be further expanded upon. Given the special importance of the equipment manufacturing industry in the manufacturing industry, it is an important guarantee for industrial upgrading and technological progress in various industries and provides a concentrated reflection of the country's comprehensive strength. This article takes the equipment manufacturing industry as its research object. The panel data of the industry is a sample, and the impact of an embedded GVC on the technical complexity of the equipment manufacturing industry's exports is specifically studied in order to enrich the existing research content. The main contribution of this article is to distinguish the embedding period and the GVC embedding method and explore the different impacts of different GVC embedding times and methods on the technical complexity of China's equipment manufacturing exports, in order to determine whether China's current equipment manufacturing embedding GVC promotes the export technical complexity of the industry.

2. Materials and Methods—Mechanism Analysis of the Impact of Embedded GVC on Export Technical Complexity

2.1. Cost Discovery Model Introducing Global Value Chain Embeddedness

With reference to the "cost discovery" model analysis framework of Hausmann et al. to investigate the impact of embedded GVC on the technical complexity of a country's exports [28], it is assumed that technological progress is Hicks neutral; that is, it does not change the ratio of capital and labor

inputs. With constant returns to scale, the Cobb–Douglas production function of a country’s export sector can be expressed as

$$Y = AK^\beta L^{1-\beta} \quad (1)$$

where Y , K , L represent a country’s total output, capital factor input, labor factor input; A represents the technical level of the sector; and β represents the elasticity coefficient of capital output. Therefore, the technology level function of the export sector can be set as $= Y/(K^\beta L^{1-\beta}) = A$, where A follows a uniform distribution within $[0, \theta]$, and θ represents the sector’s export technology level. The higher the export technical complexity, the higher the sector’s technology level; θ depends on the degree of the department’s embedded GVC (G), the number of employees in the department (H), the degree of openness of the industry (F), the intensity of R&D (R), the total number of departmental assets (K), and the number of departmental enterprises (N). Among these factors, the embedded degree of the value chain includes forward participation (G_f) and backward participation (G_b); that is, $\theta = (G_f + G_b)^\rho NRF(KH)^\varphi$, ρ, φ are constants, and $\rho, \varphi \geq 0$.

According to Hausmann’s cost discovery principle, it is assumed that a company can choose to embed GVC and not to embed GVC. If the company chooses not to embed GVC, the company uses its own technology for production. At this time, the company’s production technology level meets $A_i > \varepsilon A^{max}$, where A_i represents the production technology level of the enterprise, and ε is the efficiency of the enterprise’s imitation of technology. It is assumed that the efficiency of imitation is a function of the enterprise’s GVC embedded level and the company’s R&D investment, $\varepsilon = (G_f + G_b)^\delta R^\gamma$, where A^{max} represents the highest level of production technology in the industry. If the enterprise is embedded in GVC production, then it meets $A_i < \varepsilon A^{max}$. Suppose there are n companies in total; then, $E(A^{max}) = \frac{n\theta}{n+1}$.

It can be further determined that the expected values of enterprises that do not embed GVC to use their original technology for production and of enterprises which embed GVC to imitate the highest technology in the industry for production are as follows:

$$E(A_i | A_i > \varepsilon A^{max}) = \frac{1}{2}\theta\left(1 + \frac{n\varepsilon}{n+1}\right) \quad (2)$$

$$E(A_i | A_i \leq \varepsilon A^{max}) = \theta \frac{n\varepsilon}{n+1} \quad (3)$$

The probabilities that an enterprise does not embed GVC to use original technology for production and that an enterprise embeds GVC to imitate the highest technology in the industry for production are as follows:

$$Prob(A_i > \varepsilon A^{max}) = 1 - \frac{n\varepsilon}{n+1} \quad (4)$$

$$Prob(A_i \leq \varepsilon A^{max}) = \frac{n\varepsilon}{n+1} \quad (5)$$

Therefore, the function of the technical complexity of the export of the enterprise can be derived:

$$E(A) = \frac{1}{2}\theta\left[1 + \left(\frac{n\varepsilon}{n+1}\right)^2\right] \quad (6)$$

Substituting θ, ε into (6) gives

$$E(A) = \frac{1}{2}(G_f + G_b)^\rho NRF(KH)^\theta \left[1 + \left(\frac{n(G_f + G_b)^\delta R^\gamma}{n+1}\right)^2\right] \quad (7)$$

The above formula shows that the export technology complexity of exporting enterprises mainly depends on the GVC embeddedness (G), the number of employees in the sector (H), the degree of industry openness (F), the R&D intensity (R), the total assets of the sector (K), and the number of sector

enterprises (N). Assuming a company has a high degree of openness (F), then, the more it participates in the GVC (G), the more it will have access to foreign advanced technology and high-tech products, which will affect its own export technology complexity; the increase in R&D investment (R) will directly improve the industry export technology complexity; and the number of employees in the sector (H), the total assets of the sector (K) and the number of sector enterprises (N) directly affect the complexity of export technology through scale effects.

2.2. Mechanism of Embedded Global Value Chain on Export Technical Complexity

The promotion effect of embedded GVC on the technical complexity of industry exports can be realized through the technology spillover effect, competition effect, and scale effect. The higher the industry's openness to the outside world, the more opportunities for co-production and collaboration with multinational companies to obtain technology spillovers from developed countries, including external technology advancement and internal technology advancement. China's way of embedding GVC mainly includes two aspects: one is to conduct intermediate product trade, and the other is to introduce foreign direct investment, which will form fierce competition with domestic enterprises in terms of markets and funds. Under the competition effect, domestic enterprises are encouraged to increase their R&D investment and improve their ability to digest, absorb, and transform imported foreign technologies. The scale effect mainly refers to the division of labor and the fragmentation of production under the global value chain, which leads to the easy formation of industrial agglomerations, including vertical agglomeration and horizontal agglomeration, which are conducive to improving the productivity of the industry and increasing the overall technical complexity of the industry's exports.

However, because China has been embedded in GVC mainly by processing trade for a long time, compared with developed countries, the production links involved are relatively low-tech, and key production links and core components are controlled by developed countries. Under the capture effect of developed countries, Chinese enterprises were easily locked in the low-end production links of the global value chain for a long time; in addition, a large number of imported intermediate inputs will also have a substitution effect, continuously strengthening the dependence of enterprises on foreign imported inputs and reducing their R&D momentum.

3. Econometric Model and Data Description

3.1. Index Description

3.1.1. Export Technical Complexity

The concept of export technical complexity was originally proposed by Michaely [29]. The weighted average of the per capita GDP of each country that exports products is used to measure the technical complexity of exports. The weight is the proportion of each country's exports to the world's total exports. However, this indicator easily ignores the technological level of countries with a small proportion of global exports. Later scholars have revised the weight of this indicator. Rodrik adjusted the weight to the proportion of the total export value of a country's exports of a commodity, divided by the proportion of the world's total exports for all commodities in the world; that is, the comparative advantage index of a commodity [30]. Yao Yang and Zhang Ye constructed the domestic technical content index of exports, excluding the technical contribution of imported intermediate products to the complexity of export technologies, but did not exclude the indirect foreign technical contributions included in exports [31]. This article refers to the "new RCA index" built by the forward linkages of industrial sectors, such as Wang Zhi et al. [32], and it has a high technical complexity for exports.

The weight of the index is revised to remove the impact of imported foreign technology. The revised technical complexity index for exports is

$$PRODY_k = \sum_i \frac{(vax_{-f_i^k} + rdv_i^k) / \sum_i^n (vax_{-f_i^r} + rdv_i^k)}{\sum_k^s (vax_{-f_i^k} + rdv_i^k) / \sum_k^s \sum_i^n (vax_{-f_i^r} + rdv_i^k)} Y^i \quad (8)$$

where $PRODY_k$ is the export technical complexity index of k products, Y^i represents the per capita GDP of country i , and the former Y^i formula is the weight. The numerator indicates the ratio of the added value of the sector to the total domestic added value of the country's exports. The denominator indicates the value added by the sector in all countries' exports as a share of the total domestic added value of global exports. After calculating $PRODY_k$, we find the export technical complexity index of country c 's product k $EXPY_c^k$:

$$EXPY_c^k = \frac{(vax_{-f_i^k} + rdv_i^k)}{\sum_i^n (vax_{-f_i^r} + rdv_i^k)} PRODY_k \quad (9)$$

3.1.2. GVC embeddedness

Wang Zhi et al. [33] decomposed the value-added production V and final product production Y at the national sector level, and based on the decomposition results, defined a GVC participation index that measures a country's participation in the international production chain, and value added and final products are divided into forward GVC participation and backward GVC participation:

$$GVC_PAT_f = \frac{V_GVC}{(VA)'} \quad (10)$$

$$GVC_PAT_b = \frac{Y_GVC}{Y'} \quad (11)$$

where GVC_PAT_f indicates the forward participation of GVC, V_GVC indicates the domestic added value implicit in the export of intermediate products, and $(VA)'$ indicates the domestic added value at the national or sector level. A higher forward participation of GVC indicates that a country participates in the international division of labor. Similarly, a greater upstream inclination of Equation (11) GVC_PAT_b indicates the backward participation of GVC, and Y_GVC indicates the added value in the import of intermediate products, Y' represents the output of the final product. A higher backward participation of GVC means that a country's participation in the international division of labor tends to be downstream. The total participation index of a country's GVC is the sum of the forward participation index and the backward participation index. The larger the index, the deeper the participation in the global division of labor. This article refers to the practice of Wang Siyu and Zheng Lekai [27] and uses the GVC participation index to measure the GVC embedding degree.

3.2. Model Construction

Based on the research into the factors affecting the complexity of export technology in the existing literature, the following model is constructed:

$$Y_{it} = \alpha + \beta GVC_{it} + \gamma GVC_{it} * RD_{it} + \varphi Control + \varepsilon_{it} \quad (12)$$

where the subscript i represents the industry and t represents the year; Y_{it} is the explanatory variable representing the technical complexity of the export; GVC_{it} is the core explanatory variable, with reference to Wang Siyu and Zheng Lekai [27], which is specifically divided into the forward embedding degree (GVC_f_{it}) and the backward embedding degree (GVC_b_{it}). This article refers to Liu Lin and Sheng Bin [34], and adds the cross-terms of R&D investment (RD) and GVC embedding degree to the model to verify the impact of increasing R&D investment on the complexity of export technology while

participating in the global division of labor. ε_{it} is a random error term; “Control” represents relevant control variables, including industry openness (Freedom), research and development intensity (RD), industry concentration (Num), industry employment (Peop), and industry asset total (Asset). Among these factors, the industry openness index (Lnfree) refers to the measurement of institutional factors with reference to Li Huijuan and Cai Weihong [35]; R&D intensity (RD) and industry concentration (Lnnum) are mainly referenced by Liu Lin and Sheng Bin [34]. The specific description of each indicator is shown in Table 1.

Table 1. Control variable description.

Index	Name in the Regression Analysis	Meaning	Data Sources
Industry openness	Lnfree	Expressed by the number of foreign-invested enterprises in the industry; the greater the number of foreign-invested enterprises, the greater the degree of openness of the industry	China Statistical Yearbook
Research and development intensity	RD	Measures the strength of the industry’s technological research and development by using the proportion of the industry’s technological transformation funds as the proportion of the total internal expenditure of the industry’s scientific and technological activities	China Science and Technology Statistics Yearbook
Industry concentration	Lnnum	Expressed by the number of enterprises in the industry, the greater the number of enterprises, the more agglomerated the industry is, and the more conducive to the formation of economies of scale and promoting the technological progress of the industry	China Statistical Yearbook
Industry employment	Peop	The number of employees in each industry can reflect the size of the industry	China Statistical Yearbook
Industry asset total	Lnasset	The total assets of various industries can reflect the investment status of the industry assets and the asset scale of the industry, and are the basis for the industry’s technological research and development	China Statistical Yearbook

4. Analysis of Empirical Results

Based on the previous theoretical analysis and related data measurement, this section empirically tests the impact of the Chinese equipment manufacturing industry’s embedded GVC on the technical complexity of the industry’s exports, and explores the difference in the impact of different time periods. Then, which GVC embedding method is more conducive to the increase in the technical complexity of the industry’s exports is determined.

4.1. Overall Regression Analysis of Equipment Manufacturing Industry

The data used in this article are panel data from China’s equipment manufacturing industry from 2000 to 2014. According to the Hausman test results, fixed effects are better than mixed effects and random effects. Therefore, this paper uses a fixed effect model for regression analysis. The benchmark regression results are shown in Table 2, columns (1)–(3). Considering that there may be a two-way causal relationship between the GVC embedding degree and the technical complexity of the exports, given the possible endogenous problems of the model, this article uses the method of Lu Yue et al. [36] to select the lagging period of the GVC embedding degree as a tool variable. In the instrumental variable test, the F statistic is greater than 10, and we, therefore, reject the hypothesis that a “weak instrumental variable exists”; that is, the lagging period of the GVC embedding degree is highly correlated with the current GVC embedding degree, and there is no obvious correlation between the error terms, without directly affecting the complexity of the current export technology. Therefore, this instrumental variable meets the requirements related to endogenous variables and exogeneity. Finally, the model is re-evaluated by 2SLS. The estimated results are shown in columns (4)–(6) of Table 2.

Table 2. Estimated results of the overall regression of the equipment manufacturing industry. GVC: global value chain. RD: research and development investment.

	Benchmark Regression Results			Instrumental Variable Regression Results		
	Normal (GVC)	Normal (GVC ²)	Normal+ GVC * RD	IV	IV(GVC ²)	IV+ GVC * RD
GVC	1.478 ** (0.383)		1.126 (0.558)	1.371 *** (0.173)		0.728 *** (0.191)
GVC ²		1.744 *** (0.210)			2.126 *** (0.229)	
Lnfree	0.217 *** (0.0394)	0.232 *** (0.0330)	0.228 *** (0.0377)	0.368 *** (0.0938)	0.333 ** (0.0832)	0.341 *** (0.114)
Lnum	0.591 ** (0.182)	0.592 ** (0.194)	0.521 *** (0.111)	0.138 (0.174)	0.323 ** (0.152)	0.147 (0.200)
Peop	−0.745 ** (0.189)	−0.757 ** (0.169)	−0.653 ** (0.153)	0.290 *** (0.109)	0.115 (0.106)	0.396 *** (0.116)
Lnasset	0.125 (0.0847)	0.122 (0.0818)	0.105 (0.0739)	−0.0527 (0.0848)	−0.0653 (0.0702)	−0.112 (0.0947)
RD	0.157 (0.101)	0.127 (0.115)		0.429 *** (0.117)	0.412 *** (0.0990)	
GVC*RD			0.301 (0.277)			1.232 *** (0.437)
_cons	6.567 *** (0.626)	6.758 *** (0.697)	6.838 *** (0.415)	4.647 *** (0.468)	4.731 *** (0.445)	5.006 *** (0.478)
N	65	65	65	65	65	65
R-sq	0.771	0.793	0.759	0.824	0.855	0.809
Fixed effect	yes	yes	yes	yes	yes	yes

Note: The standard deviations in parentheses are robust; *, **, and *** indicate that they passed the significance test of 10%, 5%, and 1%, respectively.

Column (1) examines the impact of the core explanatory variable of GVC embedding and other control variables on the export technical complexity. It is found that the embedded GVC promotes the export technical complexity of the equipment manufacturing industry, and the corresponding instrument variable returns are as shown in column (4); the lag period of the GVC embedding degree is used as the core explanatory variable. It is found that the estimated coefficient of the GVC embedding degree is still positive, which is similar to the conclusion reached by Liu Lin [6]. When Chinese local enterprises participate in the global division of labor, they can introduce advanced foreign management models, import high-tech intermediate products or large machinery and equipment, and invest them in the production of domestic products to improve production efficiency. At the same time, multinational companies ensure product quality and a willingness to help Chinese companies improve production technology within a certain range; that is, the technological spillover effect brought by the embedded GVC is a major reason for the increase in the technical complexity of China's equipment manufacturing exports.

Considering that the impact of embedded GVC on the technical complexity of the equipment manufacturing export may be non-linear, column (2) regresses the horizontal direction of the GVC embeddedness and finds that the squared term of the GVC embeddedness has a significantly positive impact on the technical complexity of the export; the result of instrumental variable regression (column (5)) is consistent with the benchmark regression, and it has a greater effect on the export technical complexity, which indicates that the embedded GVC division of China's equipment manufacturing industry is conducive to the increase of the export technical complexity whether at the early or late stages of embedding. The technology spillover effect will become increasingly apparent.

In column (3), the cross term of the GVC embedding degree and technological transformation intensity is added. The estimated coefficients of $GVC * RD$ and the GVC embedding degree are still positive. Using a regression of instrumental variables, the results show that the coefficient of the cross term becomes larger and passes the 1% significance test. In addition, the estimated coefficient of the cross term is greater than the estimated coefficient of GVC, which indicates that, under the premise of the GVC being embedded in the equipment manufacturing industry, increasing the investment in technological transformation will increase the complexity of export technology. As the industry continues to open to the outside world, a large number of multinational companies flood into the local market, and domestic market competition is intensified, which encourages local companies to increase R&D investment and compete with multinational companies by improving product quality; that is, the competitive effect brought by the embedded GVC will promote Chinese equipment. The manufacturing industry has increased the technical complexity of the industry's exports.

Among other control variables, industry concentration (Num) and industry openness (Lnfree) have also been positively promoting export technology complexity. As participating in the global division of labor in the global value chain will drive equipment manufacturing companies with upstream and downstream cooperation to a certain region, or will attract related companies to enter the domestic market, this will produce an economies of scale effect, improve industry production efficiency, improve production technology, and promote the increase of industry export technology complexity; the higher the industry's GVC embeddedness, the higher the industry's openness to the outside world, and the more opportunities it has to access foreign advanced technology and promote the increase in the complexity of its own export technology.

4.2. Differential Time Period Regression Analysis

Considering that the impact of embedded GVC on the export technical complexity of the industry may be different in different time periods, this section refers to the practice of Liu Lin [6] to conduct a time-phased inspection of the research content, and we perform a segmented regression every five years as a stage in order to find the dynamic trend of the impact of embedded GVC on the technical complexity of equipment manufacturing exports. The research finds that embedded GVC has a stable positive promotion effect on the technical complexity of the industry's exports under different time periods, and this positive promotion effect will become increasingly obvious with time. The specific research results are shown in Table 3.

According to Table 3, it can be seen that the impact of embedded GVC on the technical complexity of equipment manufacturing exports has shown a positive impact; furthermore, the estimated coefficient of the GVC increased from 1.331 in 2000–2004 to 2.764 in 2010–2014, and it passed the 1% significance test. Since in the first stage, China had just joined the WTO, the equipment manufacturing industry was in the initial stage of participating in the global division of labor, the GVC embeddedness was low, and the absorption of foreign technology was low; in the second stage, as the degree of opening up to the outside world deepened, the participation in the global division of engineering deepened, while investment in research and development increased, focusing on the introduction and use of foreign, advanced technologies. Compared with the first stage, embedded GVC had a greater role in promoting the export technical complexity in the third stage. Despite the impact of the economic crisis (i.e., the industry's GVC embeddedness declined) the forward embeddedness increased, the gap between the forward and backward embeddedness gradually narrowed, and the overall level of GVC embeddedness improved. The industry gradually participated in some high-end processing and assembly and R&D design. Together with the backward embedded GVC's promotion effect on increasing the export technical complexity, the industry's production technology rapidly improved; for example, in 2013, three companies from China's XCMG Group and Sany Group entered the global construction machinery industry's top ten companies.

Table 3. Estimated results of segmented inspection.

	2000–2004	2005–2009	2010–2014
GVC	1.331 (1.050)	2.085 *** (0.443)	2.764 *** (0.307)
Lnfree	0.434 (0.254)	−0.157 ** (0.0498)	−0.208 (0.203)
Lnum	0.0806 (0.110)	2.313 (1.287)	0.108 (0.411)
Peop	0.542 ** (0.141)	−2.316 ** (0.750)	−0.279 (0.805)
Lnasset	−0.0733 (0.285)	0.294 (0.383)	0.409 ** (0.144)
RD	0.0683 (0.0779)	0.0453 * (0.0181)	0.534 ** (0.133)
_cons	3.830 ** (0.877)	3.348 (1.948)	7.956 (5.251)
N	15	25	25
R-sq	0.922	0.921	0.681
Fixed effect	yes	yes	yes

Note: The standard deviations in parentheses are robust; *, **, and *** indicate that they passed the significance test of 10%, 5%, and 1%, respectively.

4.3. Differential Embedding Method Regression Analysis

According to the previous analysis, embedding the GVC can increase the export technical complexity of the equipment manufacturing industry. This section explores which GVC embedding method is more conducive to increasing the export technical complexity of the Chinese equipment manufacturing industry. The specific GVC embedding method operates from a certain perspective, and this study found that, compared to the forward embedding degree, the backward embedding degree has a greater effect on promoting the export technical complexity of China's equipment manufacturing industry. The specific research results are shown in Table 4.

It can be seen from Table 4 that irrespective of whether GVC is embedded forward or backward, it has a positive effect on increasing the complexity of export technologies, which is consistent with the previous analysis. In addition, the horizontal comparison found that the backward embedding of GVC in China's equipment manufacturing industry has a greater role in promoting the export technical complexity. The reason for this is mainly because the Chinese equipment manufacturing industry's initial participation in the global division of labor was mainly based on simple and extensive processing trade. Developed countries that are attached to the value chain are engaged in low-tech, low-value-added processing and assembly links, and actively learn advanced foreign technologies in the backward-embedded GVC process, continuously improve their own innovation capabilities, and gradually increase the industry's export technical complexity. In addition, in recent years, China's equipment manufacturing industry has seen an upsurge in overseas mergers and acquisitions. It has gradually participated in relatively high-end production and assembly links. The industry has achieved rapid growth in the international market. The level of backward embedded GVC has also continued to increase, gradually entering the mid-to-high-end market, and the promotion of the technical complexity of the industry's exports has increased. In addition, consistent with the results obtained in the previous article, irrespective of whether it is embedded in GVC forward or backward, the degree of industrial openness (Lnfree), industry concentration (Lnum), and industry R&D investment intensity (RD) all increase the technical complexity of industry exports. It has a promoting effect, which indicates that, in the process of embedding GVC, it is necessary to continuously expand the openness of the industry,

attract industry clusters, and increase investment in research and development in the industry, so as to play the role of promoting the export technical complexity by embedding GVC.

Table 4. Regression results of distinguishing embedding methods.

	GVC Forward Embedding			GVC Backward Embedding		
	Normal (GVC_f _{it})	Normal (GVC_f _{it} ²)	Normal+ GVC_f _{it} *RD	Normal (GVC_b _{it})	Normal (GVC_b _{it} ²)	Normal+ GVC_b _{it} * RD
GVC	0.829 (0.981)		0.480 (1.160)	1.341 (0.688)		1.123 (0.842)
GVC ²		3.813 *** (0.668)			2.788 *** (0.559)	
Lnfree	0.277 *** (0.0458)	0.251 *** (0.0347)	0.285 *** (0.0448)	0.260 ** (0.0571)	0.258 *** (0.0538)	0.264 *** (0.0550)
Lnum	0.461 ** (0.125)	0.575 ** (0.162)	0.419 ** (0.117)	0.423 * (0.179)	0.383 (0.201)	0.422 * (0.172)
Peop	−0.705 *** (0.151)	−0.828 ** (0.184)	−0.653 ** (0.143)	−0.597 ** (0.175)	−0.548 ** (0.181)	−0.578 ** (0.150)
Lnasset	0.142 (0.0724)	0.150 * (0.0684)	0.133 (0.0729)	0.128 (0.0719)	0.132 (0.0748)	0.117 (0.0593)
RD	0.0917 (0.0789)	0.124 (0.106)		0.0911 (0.125)	0.0876 (0.131)	
GVC * RD			0.318 (0.536)			0.402 (0.573)
_cons	7.002 *** (0.478)	6.939 *** (0.627)	7.146 *** (0.417)	6.810 *** (0.533)	6.990 *** (0.642)	6.850 *** (0.502)
N	65	65	65	65	65	65
R-sq	0.727	0.746	0.723	0.749	0.761	0.748
Fixed effect	yes	yes	yes	yes	yes	yes

Note: The standard deviations in parentheses are robust; *, **, and *** indicate that they passed the significance test of 10%, 5%, and 1%, respectively.

5. Research Conclusions and Policy Suggestion

From the above analysis, the following research conclusions can be drawn: first, based on the benchmark regression results and the regression results of the instrumental variables, it can be seen that the coefficients of the variables are basically positive. Therefore, the embeddedness of GVC in China's equipment manufacturing industry can promote the technical complexity of the industry's exports. Second, through the regression analyses of different time periods, it is found that the degree of impact is different at different time periods. Combined with the background of the times, we can find that as China continues to open wider to the outside world, it improves its technology absorption. The embedded GVC has played a greater and greater role in promoting export technical complexity. Third, the coefficient of the cross-term of GVC embeddedness and R&D intensity is also positive, which indicates that we should increase R&D investment and technological absorption in the equipment manufacturing industry capacity so that we can better obtain the technology spillover effect brought by the embedded GVC. Fourth, both the forward embedded GVC and backward embedded GVC can promote the technical complexity of China's equipment manufacturing exports; however, compared with the forward embedding of GVC, the backward embedding has a greater effect on increasing the export technical complexity of the industry, which indicates that the current Chinese equipment manufacturing industry can also increase the export technical complexity of the industry by participating in some high-end assembly production links. Fifth, embedding GVC will cause industry agglomeration, and there will be an industry scale effect. The industry productivity will gradually increase, and eventually, it will promote the technical complexity of the industry's exports.

At present, against the background of a continuous deepening and reshaping of the GVC, China's equipment manufacturing industry is increasingly embedded in GVC. In order to increase the technical complexity of China's equipment manufacturing exports, we suggest the following measures: (1) based on the embedded GVC market, we should continue to expand the openness of the industry, actively explore overseas markets, and expand the scope of GVC embedded markets. The "Belt and Road" initiative will encourage local enterprises to "go global" and learn advanced foreign technologies; (2) China should increase investment in technology research and development, attach importance to independent innovation, improve local enterprises' ability to absorb and transform foreign advanced technologies, and strengthen the technology spillover effects embedded in GVC. Focusing on the key development areas of the equipment manufacturing industry, we should organize equipment manufacturing enterprises, universities, research institutes, etc., to jointly build a common technology and service supply system for the equipment manufacturing industry; (3) China's equipment manufacturing industry should actively participate in the production of mid-to-high-end products by overseas mergers and acquisitions, overseas project cooperation, etc., and actively integrate the R&D and design of high-end products in the chain. Furthermore, China should ensure the forward and backward embedding of the GVC to enhance the technical complexity of the industry's exports; and (4) in the process of embedding the GVC, the government should encourage multinational companies to enter the domestic market, guide basic parts and components enterprises to gather in industrial parks, and support and encourage the parks to establish industrial public service platforms. In addition, the government should try to form a group of industrial agglomerations with obvious professional characteristics and a complete service system to promote the industrial export technical complexity.

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References

1. Ma, F. Estimation of the Length and Upstream Degree of China's Manufacturing Global Value Chain and Analysis of Its Influencing Factors—A Study Based on the World Input-Output Table. *World Econ. Res.* **2015**, *8*, 3–10, 127.
2. Peng, J.; Zhang, Y. Impact of Global Value Chains on Export Technology Content of China's Manufacturing Industry. *Sustainability* **2020**, *12*, 432. [[CrossRef](#)]
3. Hu, Z.; Li, H. Embedding Global Value Chains and Technological Innovation of Manufacturing Enterprises—A Study Based on 2012 World Bank Survey Data. *J. Zhongnan Univ. Econ. Law* **2016**, *5*, 127–135.
4. Coe, D.T.; Helpman, E. International R&D spillovers. *Eur. Econ. Rev.* **1995**, *39*, 859–887.
5. Li, P.; Jiang, L. Trade Liberalization, Intermediate Product Import and China's Technology Innovation: An Empirical Study of Provincial Panel Data from 1998 to 2012. *Int. Trade Issues* **2015**, *7*, 3–11, 96.
6. Liu, L. Global Value Chain, Institutional Quality and Technical Content of Exports: An Empirical Analysis Based on Transnational Level. *Int. Trade Issues* **2015**, *10*, 37–47.
7. Peng, F.; Kang, L.; Liu, T.; Cheng, J.; Ren, L. Trade Agreements and Global Value Chains: New Evidence from China's Belt and Road Initiative. *Sustainability* **2020**, *12*, 1353. [[CrossRef](#)]
8. Li, K.; Wang, Y. Does FDI promote the quality upgrade of Chinese export products?—A study based on the dynamic panel system GMM method. *World Econ. Res.* **2013**, *5*, 60–66, 89.
9. Lu, R. Research on the Effect of Technological Progress of Chinese Enterprises under the Background of Global Value Chain Division of Labor. *Sci. Technol. Manag. Res.* **2017**, *10*, 214–219.

10. Lu, Y.; Lu, Y. Will the embedding of global value chains improve the production efficiency of manufacturing enterprises—Based on the weighted estimation of double robustness-propensity score. *Financ. Econ.* **2016**, *3*, 109–122.
11. Luo, W.; Ge, S. The Entry of Multinational Corporations and China's Independent R & D: Evidence from Manufacturing Enterprises. *World Econ.* **2015**, *38*, 29–53.
12. Lu, Y.; Chen, S.; Sheng, B. Will embedding a global value chain lead to "low-end lock-in" made in China? *Manag. World* **2018**, *34*, 11–29.
13. Dai, X.; Jin, Y. Intra-product division of labor, system quality and technical complexity of export. *Economic. Res.* **2014**, *49*, 4–17, 43.
14. Wang, L. Impact of integration of global value chains on the international division of labor status of Chinese manufacturing industry. *Stat. Res.* **2014**, *31*, 17–23.
15. Yang, H.; Tian, Y. Technology catch-up theory of evolutionary economics: Characteristics, context, key concepts and their extensions. *Learn. Explor.* **2015**, *7*, 95–99.
16. Wang, Y.; Lin, H.; Lu, C. Technological Progress Effect of Global Value Chain Embedding: An Empirical Study from Chinese Industrial Panel Data. *China Ind. Econ.* **2014**, *9*, 65–77. [[CrossRef](#)]
17. Pan, M.; Zhang, Z.; Li, H. Global value chain embedding, industrial agglomeration, and technological progress of China's industrial industry. *Ind. Technol. Econ.* **2019**, *38*, 129–136.
18. Liu, S.; Wu, H.; Ma, T.; Zhang, L.; Peng, L.; Yu, J. Using Global Value Chains to Promote Industrial Upgrade. *Int. Econ. Rev.* **2015**, *1*, 5–6, 64–84.
19. Lin, C.; Sumei, L.; Tian, Z. Financial Constraints, Trade Mode Transition, and Global Value Chain Upgrading of Chinese Firms. *Sustainability* **2019**, *11*, 4527.
20. Lu, F.; He, W.; Yang, C.; Chen, S.; Ning, L.; Mei, X. Exploring the Upgrading of Chinese Automotive Manufacturing Industry in the Global Value Chain: An Empirical Study Based on Panel Data. *Sustainability* **2015**, *7*, 6189–6211. [[CrossRef](#)]
21. David, D.; Giorgia, G.; Enrico, M. Global value chains: New evidence for North Africa. *Int. Econ.* **2018**, *153*, 42–54.
22. Tian, W.; Yu, M. Liberalization of Intermediate Trade and Enterprise R & D: An Empirical Analysis Based on Chinese Data. *World Econ.* **2014**, *37*, 90–112.
23. Xi, Y.; He, L. Is embedding a global value chain a better choice for companies to improve productivity: An empirical study based on propensity score matching. *Int. Trade Issues* **2015**, *12*, 39–50.
24. Zhang, T.; Lu, X.; Shen, Y. Embedded position of global value chain, export destination country and export product complexity. *World Econ. Res.* **2016**, *9*, 29–47, 135–136.
25. Ding, Y.; Song, C. Export market share, FDI inflow and technical complexity of Chinese manufacturing export. *Int. Trade Issues* **2019**, *6*, 117–132.
26. Liu, W.; Li, L.; Liu, Y. The impact of global value chain embedding on the complexity of China's export technology. *China Ind. Econ.* **2014**, *6*, 83–95.
27. Wang, S.; Zheng, L. Impact of Global Value Chain Embedded Features on the Differentiation of Export Technology Complexity. *Quant. Econ. Technol. Econ. Res.* **2019**, *36*, 65–82.
28. Hausman, R.; Hwang, J.; Rodrik, D. What you export matters. *J. Econ. Growth* **2007**, *12*, 1–25. [[CrossRef](#)]
29. Michaely, M. *Trade, Income Levels, and Dependence*; Elsevier Science & Technology: Oxford, UK, 1984.
30. Rodrik, D. What's so special about China's exports? *China World Econ.* **2006**, *14*, 1–19. [[CrossRef](#)]
31. Yao, Y.; Zhang, H. A Dynamic Study on the Upgrade of Domestic Technology Content of Chinese Exports—Evidence from the Country, Jiangsu Province and Guangdong Province. *China Soc. Sci.* **2008**, *2*, 67–82, 205–206.
32. Wang, Z.; Wei, S.; Zhu, K. Total trade nuclear algorithm: Official trade statistics and measurement of global value chains. *China Soc. Sci.* **2015**, *9*, 108–127, 205–206.
33. Wang, Z.; Wei, S.J.; Yu, X.D.; Zhu, K. *Measures of Participation in Global Value Chains and Global Business Cycles*; NBER Working Paper No.23222; National Bureau of Economic Research: Cambridge, MA, USA, 2017.
34. Liu, L.; Sheng, B. Domestic technical complexity of global value chains and exports: An empirical test based on Chinese manufacturing industry data. *Int. Trade Issues* **2017**, *3*, 3–13.

35. Li, H.; Cai, W. The impact of global value chain embedding on the technical complexity of China's service industry export. *Int. Trade Issues* **2017**, *1*, 70–80.
36. Lu, Y.; Huang, Y.; Chen, Y. Productivity effects of global value chain embeddings: Impact and mechanism analysis. *World Econ.* **2017**, *40*, 28–51.



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