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DOES GLOBAL VALUE CHAIN EMBEDDEDNESS PROMOTE THE NATIONAL INNOVATION CAPABILITY? ——EMPIRICAL ANALYSIS BASED ON PANEL DATA OF 62 COUNTRIES

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Abstract

Embedding global value chain (GVC) is an important means for a country to consolidate and enhance its industrial competitive advantage and innovation capability. Based on the panel data of 62 countries from 2010 to 2015, this paper empirically tests the influence of global value chain embeddedness on national innovation capability, and divides the sample into developed and developing countries according to the standard of national development level, to test the national heterogeneity of the influence of GVC embeddedness on innovation capability. The study finds that: (1) A country's forward participation can inhibit its innovation capability, while backward participation can promote its innovation capability. The effects of different participation show that embedding GVC can promote a country's innovation capability. (2) The influence of forward participation, backward participation and total participation of GVC on innovation capability presents an inverted U-shaped relationship. Over embeddedness will lead to the risks of "capture effect" and " Low-end Locking Dilemma". (3) Embedded in global value chains has national heterogeneity. Developed countries promote innovation capability through GVC forward participation, while developing countries promote innovation capability through GVC backward participation.

Keywords: global value chain; national innovation capacity; forward participation; backward participation; over embeddedness

1 INTRODUCTION

In the process of economic development, gradually narrowing the economic and technological gap with developed countries has always been one of the important issues of concern to developing countries. The world bank pointed out in the 1998-1999 development report "knowledge and development" that "on the day when knowledge becomes a strategic asset, it is precisely because of the huge technological gap that developing countries encounter a great opportunity to quickly catch up with developed countries". A large number of studies have shown that the integration of internal and external knowledge is the key to the success of innovation strategy. Therefore, for many emerging industrial countries, their innovation ability depends on absorbing the knowledge of developed countries and promoting the generation of new endogenous power through the coupling of internal and external knowledge.

Since the 1990s, the global value chains (GVC) division of labor and trade system, which is based on the division of labor within products, has become the core model to promote the expansion of global trade and the economic development of countries, providing an opportunity for emerging economies to acquire innovative knowledge and technology. According to the 2019 global value chain development report, more than two thirds of the world's trade is conducted through GVC. In order to revitalize the local economy, countries and regions increasingly rely on embedding local economic activities into the global value chain network to obtain higher value added. In this environment, the competition between enterprises has changed into the competition between the global value chains owned and embedded by enterprises, and the competition for high value-added strategic links has become the focus of competition in the current global mobile space. In this process, due to the

influence of resource endowment, economic development level and other factors, developed countries tend to obtain greater economic benefits, while the participation benefits of developing countries focus on the change of innovation ability as an important driving engine of economic growth. In view of the fact that innovation capability and quality can often affect a country's economic development trend in the next few years to a large extent, under the historical background of urgent reconstruction of the global value chain, the impact of embedding GVC on a country's comprehensive development capability based on innovation capability has become an important issue for governments and enterprises in many countries to explore.

Under the background of the changing international economic forces, it is of important theoretical and practical significance to verify whether the embedded GVC can promote the innovation ability, and to study the impact of the global value chain embedding in developing and developed countries on technological innovation, which is conducive to providing macroeconomic policy suggestions for the government and decision-making reference for the layout of enterprises' international and domestic industrial chains.

2 LITERATURE REVIEW

In recent years, the existing research focused on the impact of Embedding Global Value Chain on national innovation capability and the related research on the driving factors of national innovation efficiency, and the literature on the growth drivers of national innovation capability from the perspective of different ways of embedding GVC is relatively scarce.

The relevant research on the impact and driving factors of national and regional innovation efficiency mainly focuses on human capital investment, marketization, opening to the outside world and other aspects. Wen-qun et al. took China as an example and empirically analyzed the impact of human capital on regional innovation efficiency and stability by using heterogeneous stochastic frontier model [21]. The results showed that the innovation effect of human capital had significant heterogeneity in regions at different development stages; Bao-lin and Ming-shen pointed out that after marketization reaches a certain level, cooperative innovation of Industry-University-Research can bring increasing positive marginal effects to enterprises [2]. In addition, Liu et al. Xinshu et al., Qing-jun et al. respectively studied from the aspects of foreign direct investment (FDI) and industrial agglomeration, and demonstrated that these factors promote innovation efficiency in different degrees [12, 15, 24].

The research on the embedding effect of value chain has different conclusions. In the dynamic evolution process starting in the 1980s, emerging developing countries and regions represented by the "four Asian Tigers" and China gradually upgraded their industries while the GVC division of labor rose, and a number of powerful technology enterprises grew up; On the other hand, many developing countries participating in the international division of labor are still squeezed by developed countries through multinational companies, and have been locked in the low value-added link of the value chain for a long time [25]. Vertical specialization of production division can not only improve the R & D and innovation ability of enterprises in downstream countries through process improvement, but also bring huge "low-end lock-in" risk [26]. Therefore, there are divergent views in the existing literature: Amiti et al. proposed that through the effect of "learning in import" or "export-oriented learning" [1], developing country enterprises can obtain productivity growth that cannot be achieved only by relying on internal circulation with the help of embedded GVC. The realization mechanism of this effect was briefly summarized by Xue-min and Jie as "technology spillover, joint research and development, investment and M & a" [25]; On the other hand, based on the "capture" theory put forward and developed by Humphrey and Schmitz, Gereffi, Yue concluded that developing countries are more likely to be blocked at the end of the production and processing link due to the existing domestic market pattern at the stage of value chain upgrading [6, 10, 26], which will have a great negative impact on the scientific and technological innovation ability of the whole country, Guschanski and Onaran also supplemented and corroborated this view from the perspective of labor equity participation [7].

To sum up, the conclusion of the existing literature on the impact of global value chain embeddedness on

innovation capability is still controversial. The impact on innovation capability has not been decomposed from the perspective of different embeddedness positions in the global value chain, and the impact of different embeddedness methods on innovation capability has not been analyzed from the perspective of embeddedness degree. Therefore, based on the existing research, this paper discusses three aspects: first, put the promotion effect and inhibition effect of global value chain embeddedness on innovation capability under a unified analytical framework, and analyze the impact mechanism of global value chain embeddedness on innovation capability; The second is to use the panel data of 62 countries to empirically study the impact of global value chain embeddedness (total embeddedness, forward Embeddedness and backward embeddedness) on innovation capability; Third, according to the per capita GDP of each country, the sample is divided into developed countries and developing countries to study whether there is heterogeneity in the impact of countries' global value chain embeddedness on innovation capability at different levels of development.

3 THEORETICAL MECHANISM AND RESEARCH HYPOTHESIS

The research conclusion on the impact of global value chain embeddedness on national innovation capability has two views: the theory of promoting effect and the theory of inhibiting effect. The reason is that it is affected by the following two situational factors. The first is the embedding position. A country's participation in GVC embedding can be divided into backward embedding and forward embedding. Hummels et al. proposed quantitative indicators. Backward embedding refers to the import of intermediate goods used to produce exports, which measures the source of added value, while forward embedding represents the export of intermediate goods used by the importing country to produce exports, which measures the direction of added value [9]. The embedding position determines a country's position in participating in the international vertical division of labor, thus affecting the access to innovative resources. The second is the degree of embeddedness. There may be a threshold for the promotion of a country's innovation capability by embeddedness in the global value chain. When the degree of embeddedness is greater than the threshold, it will have a restraining effect on the innovation capability.

3.1 Promoting Effect

From the perspective of GVC backward embedding, there are two main effects. The first is the "learning in import" effect. The successful transformation of East Asia from imported assembly to all-inclusive supply is largely due to the ability to closely contact with leading enterprises, which is affected by technology transfer and knowledge spillover. On the one hand, the intermediate products imported by leading enterprises have the characteristics of high knowledge content and complex technical know-how. Supplier enterprises can learn and absorb the process technology and innovation knowledge of high-quality intermediate products by increasing R & D investment and participating in industry university research cooperation, so as to enhance the absorptive capacity of enterprises and effectively transform the technical knowledge obtained from export spillovers into the technological output of enterprise innovation [20]; On the other hand, when leading enterprises pass high standard requirements such as product design, quality and technology to OEM enterprises, OEM enterprises can be forced to catch up with the technology of leading enterprises to meet overseas needs, so as to improve R & D capability [16]. The second is the scale effect. Embedding GVC is beneficial for enterprises to explore the international market and form economies of scale. Developing economies participating in GVC carry out large-scale production through OEM mode. Due to the deepening of specialized division of labor and the increase of product sales, enterprises have reduced the average cost. As the marginal cost of innovation and quasi rent of enterprises are reduced, the innovation input of enterprises is compensated and the internal innovation power is obtained [4].

From the perspective of GVC forward embeddedness, there are three main effects. The first is the "learning by doing" effect. Based on international interaction, enterprises can obtain the export spillover of management knowledge and technical knowledge, play the learning role of human capital in practical learning, continuously improve the ability to absorb knowledge, and accumulate innovative technology experience [22]. For developing economies, "endogenous channels" are the forward embedded export spillover sources for enterprises to participate in, that is, enterprises that

provide products interact with customers with higher productivity, similar operating characteristics and more mature relationships to obtain knowledge transfer more effectively [19]; For developed economies, in order to ensure the quality of products, enterprises located in the upstream will convey design requirements, quality standards and provide talent training to the buyer, which will help enterprises accumulate and summarize production and innovation experience. The second is the effect of innovation agglomeration. Upstream enterprises outsource low value-added manufacturing tasks to offshore enterprises with low factor costs, which helps them accumulate innovation capital and focus on product design and R & D. this specialized division of labor can optimize resource allocation and promote new technology R & D and innovation activities. Finally, the competition effect. The more intense the market competition, the more significant the role of enterprises in "avoiding competition" by innovation. When there are potential competitors, in order to maintain strong control over high value-added activities, leading enterprises will improve the ability of upstream innovation, R & D and design activities and maintain market monopoly [14].

3.2 Inhibitory Effect

Although the embedding of global value chain can effectively promote the improvement of the technological content of enterprises, GVC has an embedded "improvement" range. Excessive embedding will cause the country to fall into "low-end lock". The functions of enterprises are limited to low-end links such as OEM production and assembly, and the profits of low-end enterprises are squeezed into vicious competition at low prices [18]. The inhibition of excessive embeddedness on innovation ability mainly comes from two aspects: one is that excessive dependence produces "substitution effect", which leads to the weakening or even disappearance of enterprise innovation path; The second is the "capture effect" from developed countries. Enterprises will be suppressed by developed countries' technical barriers, standards, intellectual property rights and other means to curb innovation activities.

The "substitution effect" mainly comes from the excessive backward embedding of GVC, the excessive dependence of enterprises on imported products and the path dependence of production. Import dependence stems from the fact that intermediate inputs are superior to domestic manufacturing in cost or technology, which urges enterprises to adopt the business decision of importing instead of domestic R & D. Yue verified that the "substitution effect" generated by enterprises' excessive dependence on high-quality intermediate inputs will offset the positive effect of enterprises' participation in GVC, and even "crowd out" enterprises' R & D and innovation activities [26]. Although it can be adjusted through inward procurement mechanism, state-owned ownership hinders such capacity building [27].

The "capture effect" mainly comes from the excessive forward embedding of GVC. When the distance between GVC and developed countries shrinks, it is vulnerable to the "capture effect", which has an inhibitory effect on innovation activities [8]. According to the value chain climbing mode of "process upgrading product upgrading function upgrading chain upgrading" proposed by Kaplinsky and Morris [11], and two governance forms for developed countries to snipe and control the technological upgrading of developing countries of "capture network type and hierarchical type" proposed by Schmitz [17], when developing countries achieve functional upgrading and climb to the upstream of GVC, it is often restrained by developed countries by means of anti-dumping, technical barriers, patents and intellectual property rights that capture network and hierarchical governance [23]. Ge et al. verified that GVC embedding has a negative effect on the upgrading of technology intensive industries, and to a certain extent, it encounters the technical barriers of international cooperation [5]. Yue used the double difference method to explain that enterprises with deep GVC participation and close knowledge distance from developed countries will be subject to "capture effect"[26].

According to the above theoretical mechanism analysis, this paper summarizes the following research hypotheses.

Hypothesis 1: GVC embedding can be divided into forward embedding and backward embedding. If the positive effect is greater than the negative effect, GVC embedding can promote innovation ability.

Hypothesis 2: there is an inverted U-shaped relationship between GVC embedding and innovation ability. With

the deepening of GVC, the inhibitory effect will be greater than the promoting effect, leading to the decline of innovation ability.

Hypothesis 3: due to the different ways and depths of GVC embeddedness in developed and developing countries, the impact on innovation capacity is of national heterogeneity. The promoting effect of GVC embeddedness in developing countries mainly depends on backward embeddedness, while the promoting effect of GVC embeddedness in developed countries mainly depends on forward embeddedness.

4 RESEARCH DESIGN

4.1 Measurement Model Setting

4.1.1 Benchmark measurement model

To test the hypothesis proposed, we first construct a basic model of national panel data to empirically test the basic impact of countries' participation in GVC on their innovation ability:

$$Gii_{it} = \beta_0 + \beta_1 GVC_{it} + \theta X_{it} + \varepsilon_{it} \#（1）$$

$$Gii_{it} = \beta_0 + \beta_1 GVC_{it} + \beta_2 GVC_{it}^{\ 2} + \theta X_{it} + \varepsilon_{it} \#（2）$$

GII represents the comprehensive innovation capability of country i in t years, and GVC embedding mode is represented by FP, BP and PP, respectively representing the degree of forward, backward and total participation in the global value chain. Model (2) introduces the quadratic term of GVC on the basis of model (1) to explore the nonlinear relationship between different embedding methods and innovation ability. X is the control variable vector representing other influencing factors of innovation ability, and is a random disturbance.

4.1.2 National heterogeneity test model

In order to continue to test hypothesis 3, this paper adds dummy variables for further research. The intercept and interaction terms of virtual variables are considered. The specific model is as follows:

$$Gii_{it} = \beta_0 + \delta_0 D_i + \beta_1 GVC_{it} + \delta_1 D_i \cdot GVC_{it} + \theta X_{it} + \varepsilon_{it} \#（$$

$$Gii_{it} = \beta_0 + \delta_0 D_i + \beta_1 GVC_{it} + \delta_1 D_i \cdot GVC_{it} + \beta_2 GVC_{it}^{\ 2} + \delta$$

D_i refers to the dummy variable of the national development level. It is taken as 1 when i is a developed country and 0 when i is a developing country. indicates the difference in intercept between countries, represents the difference in the slope of GVC participation, represents the difference of the quadratic coefficient of GVC participation.

4.2 Variable Description And Data Source

4.2.1 Dependent variables

This paper takes the global innovation index (GII) of 62 countries from 2010 to 2015 as the explanatory variable. The index is published in the global innovation index report jointly compiled by Cornell University, the European School of business administration and the world property organization. Considering the availability and time of data release, the innovation index data needs to lag by one period. The data in this paper are selected from the statistical report from 2011 to 2016. GII integrates the calculation of innovation input index and innovation output index. The innovation input index includes economic system, human capital and research, infrastructure quality, market maturity and business maturity indicators, and the innovation output index includes knowledge and technology output and creative output indicators.[①]

4.2.2 Explanatory variables

The explanatory variable of this paper is GVC's participation in division of labor. Referring to Koopman et al international division of labor status index [13], this paper measures a country's participation in division of labor in the global value chain from the perspective of trade value added. The specific index formula is as follows:

$$pp = \frac{IV_{it}}{E_{it}} + \frac{FV_{it}}{E_{it}} \#（5）$$

$$fp = \frac{IV_{it}}{E_{it}} \#（6）$$

① 62 countries: Argentina, Australia, Austria, Belgium, Brazil, Brunei, Bulgaria, Cambodia, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, South Korea Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Morocco, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Tunisia, Türkiye, the United Kingdom, the United States, Vietnam (sorted by the first letter of the country or region code) 62 countries: Argentina, Australia, Austria, Belgium, Brazil, Brunei, Bulgaria, Cambodia, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, South Korea Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Morocco, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Tunisia, Türkiye, the United Kingdom, the United States, Vietnam (sorted by the first letter of the country or region code)

$$bp = \frac{FV_{it}}{E_{it}} \#（7）$$

IV_{it} is the indirect value-added export volume of country i in the period t, which reflects the intermediary role of a country in the global value chain; means the added value from abroad in the export of added value of country i in the period t; refers to the total value-added exports of country i. Fp is the forward participation degree, which is used to reflect the contribution of one country's intermediate product exports to other countries' product exports; bp is the backward participation degree, which reflects the dependence of one country's export products on the intermediate products produced by other countries; pp is the total participation degree, which is the sum of the forward participation degree and the backward participation degree.

The data used to calculate the global value chain participation index in this paper comes from the OECD-TIVA database, covering G20 countries, OECD countries and some developing countries. These countries constitute the world's major innovation networks, and the sample is well representative.

4.2.3 Control variables

The control variables include economic development, development level of financial industry, degree of economic freedom, openness and industrial structure. The data are from the world bank development index database.

5 EMPIRICAL RESULTS AND ANALYSIS

5.1 Descriptive Statistics And Correlation Analysis

Table 1 is the descriptive statistics of variables. Table 2 reports the correlation coefficient matrix. There is no serious multicollinearity between variables.

Table 1 Descriptive statistics of variables

Explanatory variable	mean value	median	Maximum	minimum value	standard deviation	skewness	kurtosis
GII	45.623	45.35	68.300	23.400	10.081	0.096	-1.114
PP	45.916	44.611	79.437	23.542	9.429	0.634	1.067
BP	25.723	24.303	68.840	3.026	12.531	0.821	1.044
FP	20.193	18.605	41.248	5.990	6.998	1.137	1.178
RGDP	26.699	20.460	107.649	0.786	22.363	1.195	1.429
Private	91.147	86.136	253.262	12.690	48.604	0.695	0.149
Open	101.547	81.523	410.171	22.517	68.687	2.141	5.477
EFREE	67.352	67.600	89.400	44.100	8.380	-0.100	-0.095
Ind	94.946	96.835	99.965	62.886	5.673	-2.819	10.414

Table 2 Correlation coefficient matrix between variables

variable	GII	PP	BP	FP	RGDP	Private	Open	EFREE	Ind
GII	1.000								
PP	0.025	1.000							
BP	0.047*	0.834**	1.000						
FP	-0.051*	-0.145**	-0.668**	1.000					
RGDP	0.496**	0.227**	0.137**	0.062*	1.000				
Private	0.465**	-0.014	0.073*	-0.150**	0.470**	1.000			
Open	0.028*	0.829**	0.827**	-0.364**	0.295**	0.025**	1.000		
EFREE	0.533**	0.219**	0.150**	-0.026	0.646**	0.437**	0.312**	1.000	
Ind	0.433**	0.164**	0.038	0.154**	0.556**	0.286**	0.126**	0.529**	1.000
Vif			6.50	2.44	2.23	1.52	4.72	2.08	1.63

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively.

5.2 Analysis Of Empirical Results

5.2.1 Test of the impact of GVC embedding on innovation ability: a full sample perspective

This paper examines the impact of different GVC embedding methods on innovation ability, and the specific results are shown in Table 3. According to the regression results, the innovation capacity of a country increases by 0.142 units for each unit of GVC total embedding; Each unit of backward embedding increases a country's innovation ability by 0.26 units. GVC backward embedding has a significant positive impact on innovation ability. The results of models (2) and (4) show that the forward embedding coefficient of GVC is negative and has passed the significance level of 1%. For each unit of forward embedding increases, a country's innovation ability decreases by 0.073 units, which shows that GVC's forward embedding has a significant negative impact on innovation ability, which is inconsistent with the expectation.

In general, the possible reasons for this result are as follows: first, under the current global value chain system, most countries mainly participate in GVC through backward embedding, reduce innovation costs through imports, form scale effects, and then accumulate funds for industrial innovation and upgrading. This approach is in line with the integration path proposed by the United Nations Conference on Trade and development that most developing countries integrate into GVC first and then improve their innovation ability. Second, by participating in GVC backward embedding, we can generate the "learning in import" effect from the knowledge spillover of imported intermediate goods and the skill transfer of upstream enterprises, absorb the spillover knowledge to form a knowledge coupling, expand the boundary of skills and knowledge, so as to improve the innovation ability; Third, due to the fact that developed countries lead high value-added links through forward embedding GVC, when other countries generate competitive relations through value chain upgrading, they are prone to encounter the "capture effect" of upstream enterprises, which offsets the promotion effect of "learning by doing" effect and innovation cost agglomeration effect, thus inhibiting the growth of innovation ability. The test results verify the research hypothesis 1 that global value chain embeddedness will have a dual effect on innovation capability. Because the promotion effect is greater than the inhibition effect, most countries improve innovation capability by embedding GVC.

Table 3 Test of the impact of gvc embedding on innovation ability

Explanatory variable	(1)	(2)	(3)	(4)
Constant term	11.23016**** (1.6938)	17.0469**** (1.7909)	13.1050*** (1.6157)	11.2305*** (1.6669)
PP	0.1415** (0.0265)			
FP		-0.0725*** (0.0321)		-0.0449*** (0.0201)
BP			0.2603*** (0.0254)	0.1568* (0.0244)
RGDP	0.1699**** (0.0066)	0.1740**** (0.0079)	0.1874*** (0.0081)	0.1175*** (0.0093)
Private	0.0263**** (0.0036)	0.0266**** (0.0045)	0.0163*** (0.0029)	0.0325*** (0.0017)
EFREE	0.3785**** (0.0235)	0.3726**** (0.0246)	0.3827*** (0.0276)	0.4517*** (0.0184)
Open	-0.0393**** (0.0039)	-0.0192**** (0.0028)	-0.0062*** (0.0044)	-0.0504*** (0.0042)
R^2	0.8664	0.8552	0.8833	0.4072
F	469.6348***	427.6418***	548.2543***	41.3273***
N	368	368	368	368

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively. The standard errors of corresponding coefficients are shown in brackets.

5.2.2 Test of GVC's excessive embedding on innovation ability

The deep dependence of developing countries on the global value chain system may have negative effects on the improvement of their independent innovation ability

and even sustainable economic growth (Schmitz, 2004b). Have developing countries suffered from the "capture" or "lock-in" effect of the global value chain? The results are shown in Table 4. Models (5) - (7) show that the quadratic coefficients of forward embedding, backward embedding and total embedding are all negative, indicating that the curve is inverted U-shaped, and the thresholds are 21.725, 37.819 and 44.832 respectively. In general, different embedding methods of GVC have an inverted U-shaped relationship on innovation capability within the sample range, which shows that when the embedding level reaches a certain threshold, the inhibitory effect on innovation capability will be greater than the promoting effect, which is in line with the hypothetical expectation.

The results of models (6) and (7) show that the quadratic coefficient of forward embedding is less than that of backward embedding, and the threshold is less than that of backward embedding, which indicates that most countries are facing greater resistance to innovation effect through functional upgrading. Further, the scatter diagram in Figure 1 fits the inverted U-shaped curve of the impact relationship between FP, BP and innovation capability. From the scatter diagram of forward embedding and innovation capability in the left figure, it can be seen that the degree of forward embedding in most countries is not high, and it is concentrated near the peak of the inverted U-shaped curve. The reason is that most countries are still in the development stage of GVC forward embedding, and seek high added value through transformation and upgrading, It will touch the interests of developed countries and encounter development bottlenecks; For the countries in the second half of the inverted U-shaped curve, such as Africa, Central Asia and Latin America, GVC's forward participation largely depends on the export of raw materials such as mineral resources. For these countries whose value chain division is still engaged in low value-added links such as primary manufacturing, if it fails to integrate resources and carry out advanced innovation activities, it will be difficult to promote the improvement of innovation ability.

According to the scatter diagram of backward embedding and innovation capability in the right figure, the overall value of backward participation is larger than that of forward participation, further indicating that backward embedding GVC is the main path for most countries to participate in the global value chain system. Countries on the left side of the inverted U-shaped curve, such as Indonesia, the Philippines and other developing economies that lack independent innovation industries, can change from OEM mode to ODM and OBM mode through the "learning in import" effect to realize product and process upgrading; China and other manufacturing economies with medium technology content accumulate innovation funds by importing intermediate products and export finished products with high technology content, and generate scale effect to provide internal motivation for innovation; A few developed economies, such as Germany, Japan and the United States, use more domestic investment due to their strong industrial generating capacity. GVC's backward participation is not high, and it mainly provides innovative services by embedding high value-added links. Countries on the right side of the inverted U-shaped curve, such as Singapore, Thailand, Vietnam and other ASEAN countries, should be vigilant against the substitution effect caused by excessive dependence on imported intermediate goods, which will lead to the inhibitory effect of excessive GVC embeddedness on innovation.

On the whole, the inverted U-shaped curve embedded forward in most countries is in a downward trend, which is subject to capture effect and innovation inhibition effect; In the backward embedded inverted U-shaped curve, it belongs to the climbing stage, and the innovation resources are obtained through the promotion effect.

Table 4 Nonlinear test of the impact of gvc embedding on innovation ability

Explanatory variable	(5)	(6)	(7)
Constant term	-14.8709*** (2.8178)	-4.4174*** (2.3151)	7.8638*** (1.862)
PP	1.3629*** (0.0798)		
pp^2	-0.0152*** (0.0010)		

FP		1.8510*** (0.1059)	
fp^2		-0.0426*** (0.0022)	
BP			0.6883*** (0.0349)
bp^2			-0.0091*** (0.0006)
RGDP	0.1773*** (0.0080)	0.1434*** (0.0078)	0.1799*** (0.0118)
Private	0.0191*** (0.0048)	0.0244*** (0.0041)	0.0155*** (0.0022)
EFREE	0.3820*** (0.0229)	0.4042*** (0.0267)	0.3721*** (0.0336)
Open	-0.0053 (0.0046)	-0.0108*** (0.0029)	-0.0374*** (0.0051)
R^2	0.8667	0.9008	0.8974
F	391.2019***	546.3566***	526.4931***
N	368	368	368

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively. The standard errors of corresponding coefficients are shown in brackets.

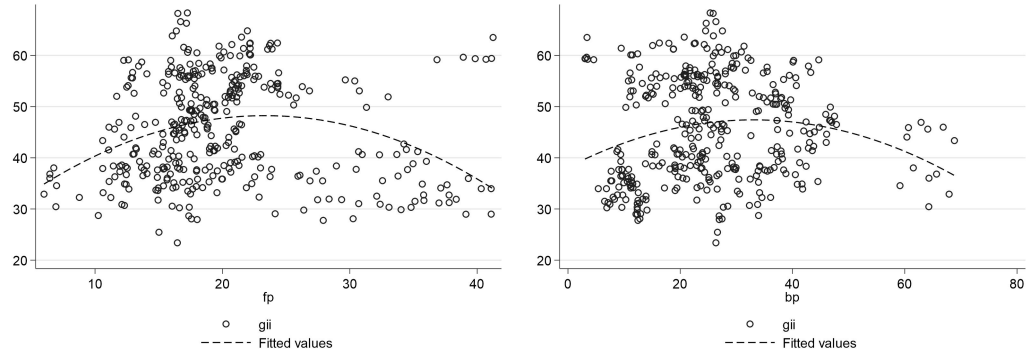

Figure 1 Fitting scatter diagram of GVC embedding and innovation capability

5.2.3 Heterogeneity analysis

From the regression results in Table 5, forward embeddedness has a significant positive impact on the innovation ability of developed countries, backward embeddedness has a significant negative impact, and embedded GVC has an inhibitory effect, but the result is completely opposite for developing countries. When the quadratic term coefficient and its dummy variable are introduced, the GVC total embedding fails the significance test, but there is an inverted U-shaped relationship between forward embedding and backward embedding. The critical values of FP and BP in developed countries are 31.988 and 11.821, respectively; The critical values of FP and BP in developing countries are 21.142 and 50.098, respectively. From the results of the critical values, the promotion effect of participating in GVC forward embedding is greater in developed countries, and the promotion effect of participating in GVC backward embedding is greater in developing countries.

The possible reasons for this result are as follows: from the perspective of developed countries, as the master of the global value chain, developed countries dominate the links and positions of the division of labor in the value chain. Because they focus on the upstream division of labor, the effect of promoting innovation ability through "learning by doing effect", innovation cost agglomeration effect and competition effect is more significant. The negative effect of the increase in backward embedding is that the developed countries' backward embedding in the professional division of labor in processing and assembly is not high, but the

level of service-oriented division of labor in manufacturing, such as marketing and management, has increased year by year. Manufacturing servitization improves the quality of export products of enterprises through vertical effect (product quality) and horizontal effect (product technology complexity), deepens the degree of forward participation, and promotes the leap of value chain [3], Therefore, backward embeddedness decreases year by year, while innovation ability increases. From the perspective of developing countries, most developing countries are embedded in the low-end downstream division of labor by virtue of the cost advantage of labor, and obtain innovation factor resources mainly through the spillover effect and scale effect generated by backward embedding. However, the forward embedding is easily captured by developed countries' patent protection and trade barriers, which greatly increases the difficulty of climbing the value chain, and thus falls into the low-end locked position.

In general, the promotion effect of innovation capability in developed countries depends on the role of forward embeddedness, while developing countries rely on backward embeddedness. Hypothesis 3 is proved.

Table 5 Heterogeneity test

Explanatory variable	(8)	(9)	(10)	(11)	(12)	(13)
Constant term	11.4273*** (2.7548)	15.5653*** (5.9527)	16.5095*** (2.4927)	0.4611 (1.7685)	11.9690*** (2.5423)	9.8746*** (2.7879)
PP	0.1421*** (0.0435)	0.0331 (0.2620)				
PP2		0.0008 (0.0030)				
FP			-0.2290*** (0.0470)	1.4038*** (0.1187)		
FP2				-0.0332*** (0.0022)		
BP					0.2373*** (0.0426)	0.4609*** (0.1278)
Bp2						-0.0046* (0.0024)
D	31.0941*** (3.1582)	-6.1703 (10.5573)	-7.0646*** (2.1822)	-8.3989*** (1.2116)	13.8869*** (1.5925)	11.5379*** (2.9663)
pp×D	-0.6123*** (0.0624)	0.8087 (0.4172)				
pp2×D		-0.0134*** (0.0042)				
fp×D			0.5283*** (0.1031)	0.7778*** (0.1418)		
fp2×D				-0.0090*** (0.0031)		
bp×D					-0.4191*** (0.4481)	-0.3616** (0.1795)
bp2×D						0.0004 (0.0028)
RGDP	0.1360*** (0.0200)	0.1809*** (0.0230)	0.0643*** (0.0213)	0.0547*** (0.0054)	0.1319*** (0.0203)	0.1472*** (0.0226)
Private	-0.0004 (0.0078)	-0.0053 (0.0080)	0.0187** (0.0076)	0.0178**** (0.0017)	0.0023 (0.0079)	-0.0044 (0.0080)
EFREE	0.3014*** (0.0410)	0.2583*** (0.0414)	0.4126**** (0.0451)	0.3679*** (0.0125)	0.3292 * * * (0.0427)	-0.0135*** (0.0435)
Open	-0.0038 (0.0080)	-0.0132*** (0.0087)	-0.0185*** (0.0050)	-0.0031 (0.0025)	-0.0218** (0.0087)	-0.0135 (0.0101)
R2	0.6340	0.6490	0.5792	0.6542	0.6162	0.6233
F	114.3291***	94.8767***	90.8484***	96.6747***	105.9764***	84.5837***
N	470	470	470	470	470	470

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively. The standard errors of corresponding coefficients are shown in brackets.

5.2.4 Robustness and endogenous test

The robustness test of the explanatory variable lags behind one period. In order to ensure the robustness of the regression results, this paper uses GVC total embedding, forward embedding and backward embedding variables as explanatory variables. The regression results are shown in Table 6. All variables of the model (14) - (19) passed the significance level test of 1%, and the regression results are basically consistent, which can judge that the estimation results of the benchmark regression model are robust.

Table 6 Robustness test

Explanatory variable	(14)	(15)	(16)	(17)	(18)	(19)
Constant term	10.438*** (1.7803)	12.8615*** (1.6289)	16.7148*** (1.7757)	-16.9145*** (2.6075)	5.2344* (2.7416)	7.6928*** (1.6496)
PP (-1)	0.1672*** (0.0268)			1.4348*** (0.0820)		
FP (-1)			-0.0584* (0.0347)		1.9211*** (0.1498)	
BP (-1)		0.2776**** (0.0259)				0.7182*** (0.0381)
PP (-1) 2				-0.0516*** (0.0010)		
FP (-1) 2					-0.0445*** (0.0037)	
BP (-1) 2						0.0088*** (0.0006)
RGDP	0.1679*** (0.0062)	0.1836*** (0.0081)	0.1726**** (0.0077)	0.1739**** (0.0066)	0.1399*** (0.0073)	0.1789*** (0.009)
Private	0.0266*** (0.0037)	0.0175*** (0.0033)	0.0269*** (0.0044)	0.0176*** (0.0024)	0.0241*** (0.0047)	0.0159*** (0.0024)
EFREE	0.3802*** (0.0249)	0.3841**** (0.0285)	0.3730**** (0.0247)	0.3887*** (0.0222)	0.4105*** (0.0286)	0.3752*** (0.0300)
Open	-0.0429*** (0.0035)	-0.0645*** (0.0042)	-0.0187*** (0.0029)	-0.0109 * * * (0.0047)	-0.0110*** (0.0033)	-0.0479*** (0.0046)
R2	0.8699	0.8855	0.8549	0.8676	0.8987	0.9026
F	484.27***	560.14***	426.72***	394.17***	533.96***	557.57***
N	368	368	368	368	368	368

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively. The standard errors of corresponding coefficients are shown in brackets.

Endogenous test of instrumental variables. In order to deal with the endogenous problem caused by missing variables and the interaction between innovation index and global value chain participation, this paper uses GVC total embedding, forward embedding and backward embedding variables as instrumental variables, and uses the two-stage least square method to estimate. The regression results are shown in Table 8. All variables in the model pass the 1% significance level test, and the sign direction of all variables is consistent with the above, Therefore, the results of this study are still robust.

Table 7 Endogeneity test

Explanatory variable	(20)	(21)	(22)	(23)	(24)	(25)
Constant term	9.7181*** (1.8910)	12.4827*** (1.5627)	16.8446*** (1.6601)	-19.1375*** (3.2481)	-6.1382*** (2.1971)	6.9894*** (1.7851)
PP	0.1805***			1.5231***		

	(0.0257)			(0.0919)		
FP			-0.0630*** (0.0180)		1.9675*** (0.0716)	
BP		0.3050 * * * (0.0306)				0.7419*** (0.0411)
PP2				-0.0164*** (0.0010)		
FP2					-0.0449*** (0.0012)	
Bp2						0.0087*** (0.0006)
RGDP	0.1681*** (0.0057)	0.1882*** (0.0069)	0.1735 * * * (0.0073)	0.1793 * * * (0.0094)	0.1412*** (0.0073)	0.1806*** (0.0116)
Private	0.0262*** (0.0024)	0.0148*** (0.0018)	0.0267*** (0.0034)	0.0167*** (0.0016)	0.0241*** (0.0031)	0.0137*** (0.0016)
EFREE	0.3849*** (0.0215)	0.3874 * * * (0.0233)	0.3725 * * * (0.0195)	0.3845*** (0.0232=3)	0.4105*** (0.0247)	0.3809*** (0.0311)
Open	-0.0451*** (0.0037)	-0.0697*** (0.0051)	0.0188*** (0.0026)	-0.0099 * * * (0.0048)	-0.0096*** (0.0021)	-0.049*** (0.0068)
R2	0.8646	0.8831	0.8553	0.8684	0.9012	0.8972
F	475.94***	561.08***	427.10***	405.37***	539.16***	544.23***
N	368	368	368	368	368	368

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels respectively. The standard errors of corresponding coefficients are shown in brackets.

6 CONCLUSIONS AND SUGGESTIONS

Using GVC embedding data and innovation capability data from 62 countries from 2010 to 2015, this paper empirically tests the impact of GVC embedding on innovation capability. Through the above empirical analysis, we can find the following conclusions: (1) a country's forward embeddedness through the global value chain will have an inhibitory effect on its innovation ability, while backward embeddedness will have a promoting effect on its innovation ability. Integrating the dual effects of different embeddedness methods, embedding in GVC will promote the improvement of a country's innovation ability. (2) GVC forward embeddedness, backward Embeddedness and total embeddedness have an inverted U-shaped relationship with innovation ability. There is a threshold for different embeddedness methods. When the embeddedness degree exceeds the threshold, it will have an inhibitory effect on innovation ability. (3) Countries with different levels of development have different ways and degrees of embedding into the global value chain, and the impact on innovation capability has national heterogeneity. Developed countries promote innovation capability through forward embeddedness in the global value chain, while developing countries promote innovation capability through backward embeddedness in the global value chain.

As far as China is concerned, although China, as a "world factory", is deeply involved in the global value chain, it generally presents a "large but not strong" pattern, mainly engaged in the middle and low-end links of production, manufacturing, assembly and processing, and has a low share of exports in high-tech, capital goods and services exports and other high value-added fields, which is very similar to the assumptions of developing countries in this paper, This paper has important implications for China's future development: (1) under the current AI revolution trend, China should use its advantages under the international division of labor system to enhance the breadth and depth of global value chain embedding, strengthen production cooperation with other countries, so as to enjoy the innovation promotion effect brought by the technology spillover of global value chain. (2) With the rise of trade unilateralism and the weakening of labor cost advantage, China should pay attention to its own scientific and technological research and development ability to achieve a virtuous cycle of rising value chain and independent innovation technology. The development

strategy of "forming a new development pattern with domestic circulation as the main body and domestic and international double circulation promoting each other" highlighted during the two sessions in 2020 points out the direction for China to explore the upgrading path of the global value chain. China should realize the core development of the domestic value chain, the construction of the "one belt one road" regional value chain and the remodeling of the global value chain. First, adjust the layout of domestic industries, promote the innovation ability of domestic links in the value chain, and promote the development of key links such as chip R & D and software development through market incentive policies such as taxes and R & D subsidies, so as to develop the core missing links in the upstream industry chain and drive the upgrading of downstream links. Secondly, we should give full play to China's relative technological advantages in the "belt and road" value chain, accelerate the implementation of international production capacity cooperation, guide industrial gradient transfer, effectively use the innovation cultivation environment of enterprises, pay attention to the transformation from factor driven to innovation driven, realize economic transformation and upgrading, and promote high-end economic development. Finally, it is an effective upgrading path for developing countries to open up the global value chain by leading enterprises to obtain strong brand ability and dominant power of industrial development in the domestic competition and the competition of member countries in the region, and then integrate and reshape the division of labor system of the global value chain to form a cooperative relationship with developed countries that shares interests and is equal in strength.

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