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Asymmetric Game Analysis of China's Equipment Manufacturing Industry Hollowing-out

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Abstract

With the rapid development of global economic integration, industrial hollowing-out problem has been paid much attention by foreign and domestic scholars. Based on the current situation of China's equipment manufacturing industry, the asymmetric game model is created in this paper which integrates the strong multinational companies and the weak Chinese local companies into a united system. Considering the influence of two main factors affecting unit production cost, technology and production factor cost, importance is attached on analyzing equilibrium solutions of the asymmetric game between multinational company and Chinese local company in R&D stage and processing stage of global value chain, so as to explain the formation mechanism of China's equipment manufacturing industry hollowing-out. Suggestions for breaking through the hollowing-out obstacle are put forward accordingly.

Keywords: Industrial Hollowing-Out; China's Equipment Manufacturing Industry; Asymmetric Game; Global Value Chain.

1. Introduction

The equipment manufacturing industry is the basic industries and the core component of the manufacturing sector to provide all kinds of technical equipments to economic development and national security, which is an important symbol of a country's level of development and regional scientific and technological progress and competitiveness. The development of China’s equipment manufacturing industry depends on its domestic industrial growth, also the global network of division of labor dominated by developed countries. In order to narrow the gap between China’s equipment manufacturing industry and those of the developed countries, China’s equipment manufacturing industry integrated into the global value chain through different channels such as trade and foreign direct investment. Now the production and export scale of China’s equipment manufacturing industry are among the world top, China has also firmly established itself as one of the world’s equipment manufacturing industry superpower.

However there are more problems while China achieves. Although China's equipment manufacturing industry integrates into the global value chain, it is at the expense of the massive consumption of resources and severe plunder of cheap labor power. As a result, China integrates into low-end of the global value chain and is in a low-locked awkward position.

After the financial crisis, the global economy has undergone a series of adjustments and changes and entered into a slowdown, adjustment and transformation and increasing competition period. When the global economic situation has undergone these significant changes, the drawbacks of low-locked integration of China's equipment manufacturing industry continue to appear. The multinational disinvestment, declining international competitiveness and higher dependence on foreign technology in Chinese manufacturing sector show that hollow-out has been becoming largest hidden danger of China's equipment manufacturing industry. Therefore, the goal of this paper is to analyze the gap between multinational and local companies by establishing Stackelberg model, and then try to reveal the gaps and variations between the two firms, i.e. the multinational company and the Chinese local company, which can be used to explain the formation mechanism of Chinese equipment manufacturing industry hollowing-out.

2. Literature Review

Since its advent for the first time in the second half of the nineteenth century in UK, industrial hollowing-out has been paid more and more attention by scholars. Industrial hollowing-out in general sense is caused by rapid development of transnational corporations and outward foreign direct investment, which is evident in United States, Japan and other developed countries. For a developing country like China, it is still in the third phase of John Dunning's (1981)[1] description about international direct investment, or mainly absorbing inward foreign direct investment, so that its meaning, manifestation and formation mechanism of industrial hollowing-out has particularity and is different from those in general sense (Hewings, Sonis & Guo, 1998[2]; Hsu & Liu, 2004[3]). The related research will be very interesting and meaningful.

As to China's equipment manufacturing industry problems caused by multinational behavior, current research mostly focus on the factors affecting China's equipment manufacturing industry innovation, and exploring the reasons and putting forward countermeasures accordingly, which could be divided into the following three categories:

Firstly, analysis is done from the perspective of market demand and market competition. Chen (2008)[4] believes that the lower technical level of China's equipment manufacturing industry makes its competitiveness, which put it into low-end of the global value chain, while multinational companies squeeze profit margin of China's equipment manufacturing industry through vertical competition, strengthen the following features in technology of the latter, and then restrict independent innovation ability and power of China's equipment manufacturing industry through intensifying horizontal competition in global production networks. Sun and Liu (2010)[5] believes that lacking of innovation capability in China's equipment manufacturing industry is due to the shrink in effective demand scale and the decrease in demand level in open economy.

Secondly, analysis is carried out from the view of industrial agglomeration. Zhang (2002)[6] finds that location advantage and social and economic development level are the foundation of China's equipment manufacturing industry, attracting and utilizing foreign capital is the strong driving force, and capital structure diversification is the active factor. Meng (2010) [7] finds that industrial agglomeration can significantly influence total factor productivity of China's equipment manufacturing industry through technological progress and efficiency improvement.

Thirdly, analysis is held from the angle of industry chain and value chain. Duan and Li (2008)[8] believe that there are serious safety problems in China's equipment manufacturing industry, which is caused by the serious dependence on import of major technical equipment and the low level of equipment export. Chen and Liu (2011)[9] point out that developed countries' equipment manufacturing industries occupy the high-end of global value chain through investment in advanced technology and service elements, while China's equipment manufacturing industry lags behind, and cannot provide advanced technical equipment to local upstream and downstream firms, which is difficult to support local upstream and downstream companies to climbing up the high-end of value chain, therefore has serious obstacles in industrial upgrading. Zhou, Lan & Fu(2014)[10] indicated that the low-end GVC embedded mode has caused a significant

decline in the position of global value chain to China's equipment manufacturing industry. Particularly, over-reliance on processing trade and foreign investment also will lock themselves into the low-end of global value chain and inhibit the technology development (Hatani, 2009[11]; Chen & Zhong, 2014[12]), which will often affect the industrial safety of China's equipment manufacturing industry (Liu, 2001[13]; Wu & Liu, 2012[14]) and trigger Chinese-style industrial hollowing-out problem.

From the literatures above, it is not difficult to find there is not enough research on the competition effect of multinational equipment manufacturing companies and the reaction of China's domestic equipment manufacturing companies. How to analyze the relationship between multinational equipment manufacturers conflict with China's domestic equipment manufacturing companies? What about the final outcome of the conflict between them? An improved Stackelberg game model will be created in this paper, which integrates the strong multinational companies and the weak local companies into a united and interactional system, so as to analyze the hollowing-out problems brought about by the low-end development mode of China's equipment manufacturing industry in global value chain.

The other parts of this paper will be listed as follows: In part 3 the research hypotheses and model will be built up; in part 4 we will use the model above to explain the formation mechanism of China's equipment manufacturing industry hollowing-out; then come to conclusions and put forward decision implications for China accordingly in part 5.

3. Research Hypotheses and Model

3.1 Research Hypothesis

The traditional Stackelberg game model assumes the existence of two firms in unequal status but producing same products. These two companies are faced with a common market, and they determine their market share and profits respectively through output decision under the condition of complete information. Inverse demand function in product market is $p(Q) = a - bQ = a - b(q_1 + q_2)(a, b > 0)$, where p represents the market price the two firms faced with, q_1 represents the quantity decision of firm 1, q_2 represents the quantity decision of firm 2. The two firms decide their output successively, where firm 1 (Leader) determines its output first, and firm 2 (Follower) makes its output decision based on firm 1's output.

However, this traditional Stackelberg model assumes that the marginal cost of the two firms' products is fixed, which cannot be used in analyzing hollowing-out problem in this paper directly, since the gap in technological level and production factor cost between multinational company and Chinese local company may lead to variable marginal costs.

The aim of constructing the model is to place the multinational enterprises and the China enterprises in a system to convert the model by adding different variables, thus obtains the quality changes in the global division of labor in the multinational companies and Chinese enterprises. According to the gap between the two firms, to analyze the reasons for the formation of China's equipment manufacturing industry hollowing out.

Therefore, assuming multinational company who has higher technological level as firm 1 (Giuliani, Pietrobelli & Rabellotti, 2005) [15] and Chinese local company as firm 2, modifications are made to the marginal cost assumption of traditional Stackelberg model, where there are two main factors affecting unit production cost of multinational company and Chinese domestic company:

The first is technology. Advanced technology can improve the process technology, optimize resource utilization efficiency and improve labor productivity, then reduce the production cost. Multinational company with advanced technology can effectively reduce its unit production cost, while the Chinese local company with comparative disadvantage at technological level has relatively higher unit production cost. Therefore, technology level and unit

production cost are negatively correlated, and the correlation coefficient could be denoted by $\alpha(0<\alpha<1)$.

The second is production factor cost, which refers to a variety of expenditures needed for social production and management activities, including direct materials, direct labors and manufacturing expenses. Direct materials include raw materials, energy and semi-finished products consumed in production; direct labors include wages and welfare of employees directly engaged in production; manufacturing expenses include all kinds of indirect costs in organization and management of production, such as maintenance and depreciation expenses of plant and machinery. The different production factor endowments of multinational company and Chinese local company determine the different unit product cost of the two companies. Chinese local company with comparative advantage can effectively reduce production cost, while multinational company with comparative disadvantage has relatively higher unit production cost. Therefore, production factor cost and unit production cost are positively correlated, and the correlation coefficient could be denoted by $\beta(0<\beta<1)$.

3.2 Model Construction

Based on the model assumptions above, the constant unit production cost $c(0<c<a)$ is introduced here. Since the multinational company has comparative advantage in technology and comparative disadvantage in production factor cost while the Chinese local company has comparative disadvantage in technology and comparative advantage in production factor cost, therefore, the unit production cost of the multinational company can be assumed as $C_1=(1-\alpha+\beta)c$, and the unit production cost of the Chinese local company can be assumed as $C_2=(1-\beta+\alpha)c$.

Then the profit functions of the two companies are as follows:

$$\Pi_1=q_1\left(p(Q)-C_1\right)=q_1\left[a-b\left(q_1+q_2\right)-\left(1-\alpha+\beta\right)c\right] \quad (1)$$

$$\Pi_2=q_2\left(p(Q)-C_2\right)=q_2\left[a-b\left(q_1+q_2\right)-\left(1-\beta+\alpha\right)c\right] \quad (2)$$

Different from the traditional Stackelberg game model, we assume that the marginal costs of the two companies' products are variable, and are changed with the relative variation of two correlation coefficients α and β. The size of α is decided by the impact level of technology on unit production cost, and the size of β is decided by impact level of production factor cost on unit production cost. The size of α and β is also influenced by the different industries in study.

3.3 Model Solutions

The game model above is a dynamic game model under complete and perfect information. Therefore, backward induction method can be adopted here to solve the sub-game perfect Nash equilibrium. The basic idea of backward induction method is to start analysis from the final stage of a dynamic game and determine choices of players in this stage, then determine choices of players in the previous stage.

In the game between multinational equipment manufacturing company and China's local equipment manufacturing company, when firm 2 (Chinese company) makes decision in the second stage, the output of firm 1 (multinational company) $q_1(q_1 \geq 0)$ has already determined, and firm 2 knows the decisions of firm 1. For firm 2, it should determine its output $q_2(q_2 \geq 0)$ according to the given output decision of firm 1 so as to maximize its own profit. That is to say,

$$\begin{aligned}\max \Pi_2 &= \max q_2\left(p(Q)-C_2\right)\\ &= \max q_2\left[a-b\left(q_1+q_2\right)-\left(1+\alpha-\beta\right)c\right]\\ &= \max q_2\left(a-bq_1-bq_2-c-\alpha c+\beta c\right)\end{aligned} \tag{3}$$

The first-order optimization condition of formula (3) is

$$\frac{\partial \Pi_2}{\partial q_2}=a-bq_1-2bq_2-c-\alpha c+\beta c=0$$

$$q_2=\frac{1}{2b}\left(a-bq_1-c-\alpha c+\beta c\right) \tag{4}$$

Then q_2 of formula (4) is the actual output selection of firm 2 based on the output choice q_1 of firm 1. Because the information is complete, firm 1 is bound to predict that firm 2 will produce q_2 when it selects to produce q_1. Therefore firm 1 will produce q_1 in the first stage so as to maximize its profit. That is to say,

$$\begin{aligned}\max \Pi_1 &= \max q_1\left(p(Q)-C_1\right)\\ &= \max q_1\left[a-b\left(q_1+q_2\right)-\left(1+\beta-\alpha\right)\right]\\ &= \max q_1\left(a-bq_1-bq_2-c-\beta c+\alpha c\right)c\end{aligned} \tag{5}$$

Substituting formula (4) into formula (5) could get first-order optimization condition.

$$\frac{\partial \Pi_1}{\partial q_1}=\frac{a}{2}-bq_1-\frac{c}{2}+\frac{3}{2}\alpha c-\frac{3}{2}\beta c=0$$

$$q_1=\frac{a-c}{2b}+\frac{3c\left(\alpha-\beta\right)}{2b} \tag{6}$$

Substitute formula (6) into formula (4) could get

$$
\begin{aligned}
q_2 &= \frac{1}{2b}\left(a - bq_1 - c - \alpha c + \beta c\right) \\
&= \frac{1}{2b}\left[a - b\left(\frac{a-c}{2b} + \frac{3c(\alpha-\beta)}{2b}\right) - c - \alpha c + \beta c\right] \\
&= \frac{1}{2b}\left(\frac{a}{2} - \frac{c}{2} - \frac{5}{2}\alpha c + \frac{5}{2}\beta c\right) = \frac{a-c}{4b} - \frac{5c(\alpha-\beta)}{4b}
\end{aligned} \tag{7}
$$

Therefore, the solutions for sub-game perfect Nash equilibrium are as follows.

$$
(q_1, q_2) = \left(\frac{a-c}{2b} + \frac{3c(\alpha-\beta)}{2b}, \frac{a-c}{4b} - \frac{5c(\alpha-\beta)}{4b}\right) \tag{8}
$$

4 . Explain China's Equipment Manufacturing Industry Hollowing-out using the Model above

There are four constants a, b, α and β in the equilibrium solutions above, where a and b are nonzero invariant constants, α and β are nonzero variant constants which are influenced by the features of industries. In the global value chain of equipment manufacturing industry, Chinese local company competes with multinational company mainly in two stages, say R&D stage and processing stage. The feature of the same industry will be changed in different stages of global value chain; it is technology-intensive in R&D stage and labor-intensive in processing stage. Therefore, we can analyze the equilibrium solutions above further.

4.1 R&D Stage

In R&D stage, equipment manufacturing industry is technology-intensive, which requires complex and sophisticated science and technology in order to carry out the work of production and service and is more dependent on technology while less dependent on production factors. Improvements in technology and innovation can greatly reduce the unit production cost, while the effects of production factor cost on unit production cost is lower, that is $0 < \beta < \alpha < 1$. In this stage, the equilibrium solutions to multinational company and Chinese local company are still the same as formula (8). However, when we consider the comparison between α and β, that is $0 < \beta < \alpha < 1$, or $0 < \alpha - \beta < 1$, then relationship between q_1 and q_2 will be as follows:

$$
\begin{cases}
q_1 = \dfrac{a-c}{2b} + \dfrac{3c(\alpha-\beta)}{2b} > \dfrac{a-c}{2b} \\
q_2 = \dfrac{a-c}{4b} - \dfrac{5c(\alpha-\beta)}{4b} < \dfrac{a-c}{4b} = \dfrac{1}{2}\left(\dfrac{a-c}{2b}\right)
\end{cases} \tag{9}
$$

$$
\Rightarrow q_2 < \frac{1}{2}\left(\frac{a-c}{2b}\right) < \frac{1}{2}q_1
$$

According to formula (9), we know that when multinational company and Chinese local company compete in R&D

stage of global value chain, multinational company has first-mover advantage with market share reaching above $2/3$ of the total market volume, while China's local company only occupy less than $1/3$ of the total market share. With the development of technology, the change between α and β will lead to bigger gap between q_1 and q_2, the result is that the market share of multinational company is continuously becoming larger, and the marker share of China's local company is becoming smaller and smaller, finally China's local company may be gradually squeezed out of R&D stage.

4.2 Processing Stage

In processing stage, equipment manufacturing industry is labor-intensive, which mainly depends on labors in production and has fewer requirements on technology. In this stage, production factor cost affects unit production cost greatly, while technology has a lower influence on unit production cost, that is $0<\alpha<\beta<1$, or $0<\beta-\alpha<1$, then relationship between q_1 and q_2 will be as follows:

$$\begin{cases} q_1 = \dfrac{a-c}{2b} + \dfrac{3c(\alpha-\beta)}{2b} < \dfrac{a-c}{2b} \\ q_2 = \dfrac{a-c}{4b} - \dfrac{5c(\alpha-\beta)}{4b} > \dfrac{a-c}{4b} = \dfrac{1}{2}\left(\dfrac{a-c}{2b}\right) \end{cases} \tag{10}$$

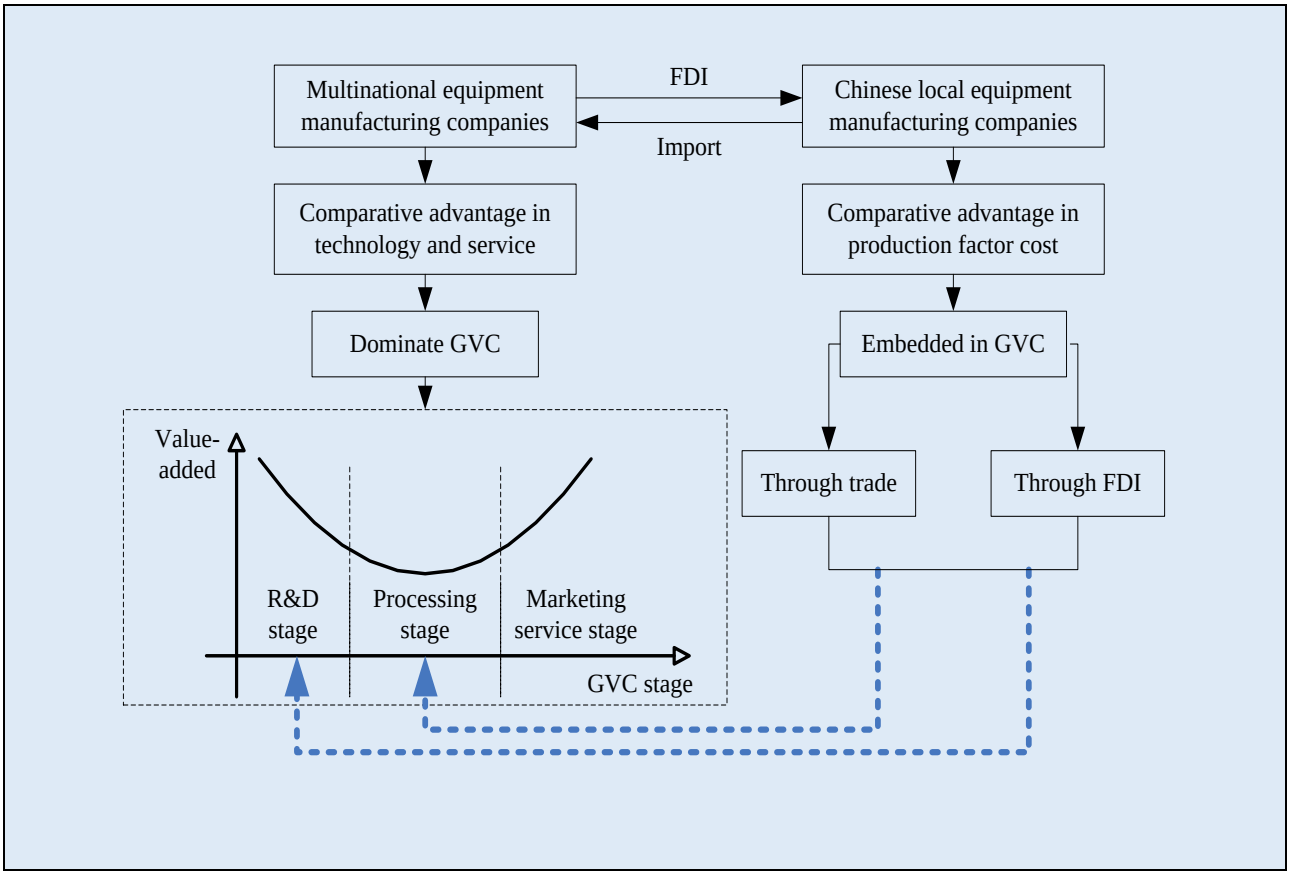
$$\Rightarrow q_1 < \frac{a-c}{2b} < 2q_2$$

According to formula (10), we know that when multinational company and Chinese local company compete in processing stage of global value chain, Chinese local company will make use of its comparative advantage on lower production factor cost to make its market share reach above $1/3$ of the total market volume, while multinational company decreases its market share to less than $2/3$. This will give an incentive to Chinese local company to depend more and more on its lower production factor cost, such as environment pollution and labor expenditure, so as to enlarge its market share in this stage. Finally, Chinese local company will be fixed in this processing stage.

4.3 Formation Mechanism of Hollowing-out

We know that China's equipment manufacturing industry integrated into the global value chain (GVC) through different channels such as trade and foreign direct investment. But this kind of integration in conducted by multinational companies in developed countries, which initiatively transfer the segments of value chain with no competitiveness to developing countries like China through direct investment and import and focus on the process of high value-added strategic value chain. In the global value chain of equipment manufacturing industry, multinational companies dominate the R&D stage and marketing service stage, and push Chinese local companies into the processing stage, which can be shown by Figure 1.

Fig. 1: Division Mode of Equipment Manufacturing Industry in GVC



Combined with the results of Stackelberg game model equilibrium, in the high-end of global value chain (R&D stage), due to the higher demands on the technical level, the multinational equipment manufacturing company with technological advantage make its product's market share large, Chinese local equipment manufacturing company only gets smaller market share due to technical comparative disadvantages. At the low-end of global value chain (Processing stage), there are greater demand for factors, China domestic equipment manufacturing company occupies larger market share due to the comparative advantage of factor cost, the multinational equipment manufacturing company's market share decreases due to the comparative disadvantages in factor cost. Therefore, China's local equipment manufacturing company lying in the processing stage (the low-end of value chain) and multinational equipment manufacturing company lying in the R&D stage (the high-end of value chain) should be the Nash equilibrium solution to this game.

Through the above analysis, we can come to the conclusion that: in the perspective of the global value chain, multinational equipment manufacturing companies with technology advantage occupy the high-end of the value chain, and continuously induce China local companies to seek advantage of production factors through foreign direct investment. At the beginning, the latter may compete with the former in R&D stage and processing stage of the global value chain, through asymmetric game mentioned above, we know that the technology gap between multinational company and Chinese local company becomes larger and larger, multinational company occupies more and more market share and squeeze Chinese local company out of the high value-added R&D stage, while at the same time, multinational company gives incentives to Chinese local company through FDI and import and fixes the latter into the low value-added processing stage. In the long run, China's equipment manufacturing industry will be locked in the low-end position of GVC, lacking of the ability to climb up high-end of the value chain and existing potential risk of hollowing-out. In the

post financial crisis era, developed countries return to the real economy, putting forward "Re-industrialized strategy". Using its dominant position in the global value chain, on one hand, the developed countries promote the development of high value-added core segments in the industry chain, such as sophisticated equipment, core components and equipment manufacturing services; on the other hand, they transfer the processing and assembling segments to lower-cost developing countries. Subsequent problems such as trade collapse, overcapacity and multinational companies' mass disinvestment, are increasingly turn the potential risk of hollowing-out into real restriction, which limits the development of China's equipment manufacturing industry.

5. Conclusions and Decision Implications for China

A Stackelberg game model is created in this paper to indicate the asymmetric status of multinational company and Chinese local company in the global value chain of equipment manufacturing industry and analyze the formation mechanism of China's equipment manufacturing industry hollowing-out. Different from the traditional Stackelberg model, changes are made on two main factors affecting unit production cost, technology and production factor cost. According to analysis on the equilibrium solutions of the game model in R&D stage and processing stage of GVC, we can draw the conclusion that multinational company with technical comparative advantage occupies the high value-added R&D stage of global value chain, while Chinese local company only relies on its comparative advantage on production factor cost to initiatively enlarge production in the low value-added processing stage of global value chain. The multinational company also makes use of its dominant position in global value chain to decrease Chinese local company's technological and marketing ability, and then weaken its independent innovation ability and impetus, so that China's equipment manufacturing companies are locked in the low-end embarrassing position of global chain, thus greatly reducing the upgrading capability and industrial safety of China's equipment manufacturing industry, which is a kind of Chinese-style industrial hollowing-out.

The analysis and the conclusions drawn in this paper can provide certain decision implications for China: to break through this kind of Chinese-style industrial hollowing-out, China needs to change its embedded mode in global value chain. On one hand, China's equipment manufacturing industry cannot always rely on comparative advantage in low cost products and be satisfied with the amount of foreign capital utilization, but should continue to increase the export of high value-added products, deal with the relationship between foreign capital dependence and its own economic development, and transform from the focus on the number of foreign capital into the quality of foreign capital so as to actively climb up the high-end of global value chain; on the other hand, China's equipment manufacturing industry should correctly handle the relationship between the global value chain and its domestic industry chain, treat embedding the global value chain as an important way to enhance its competitiveness instead of the ultimate goal. Through utilizing a variety of organic combination of embedded mode, China's equipment manufacturing industry also should not only optimize the embedded effects through trade and FDI, but also capture strategic stage in the global value chain through outward foreign direct investment, so as to enhance the safety and the ability to upgrade for the whole equipment manufacturing industry chain.

References

[1] Dunning John H.: Explaining the international direct investment position of countries: toward a dynamic and development approach .Weltwirtschaftliches Archiv. 117 (5), 30-64 (1981)

[2] Hewings G., Sonis M. & Guo J.: The hollowing-out process in the Chicago economy. Geographical Analysis. 30(3), 217-233 (1998)

[3] Hsu C. M., Liu W. C.: The role of Taiwanese foreign direct investment in China: economic integration or hollowing-out? The Journal of the Korean Economy. 5(2), 207-231 (2004).

[4] Chen Aizhen: Restriction on and breakthrough in innovation of China's machinery industry: a study based on the competition in GVCs. Journal of Nanjing University (Philosophy, Humanities and Social Sciences. 45(1), 36- 45 (2008)

[5] Sun Xiaohua, Li Zhuanjie: Effective demand scale, double-demand structure and industrial innovation capability: evidence from China's equipment manufacturing industry. Research Management. 31(1), 93-103 (2010)

[6] Zhang Wei: Industrial concentration of equipment manufacturing in China. China Industrial Economics. (3), 55-63 (2002)

[7] Meng Qi: Industrial agglomeration and technology advance - the empirical analysis based on the China's equipment manufacturing industry. Science & Technology and Economy. 23 (1), 67-70 (2010)

[8] Duan Yiqun, Li Dong: An empirical analysis of the impact of import and export on the industry security of equipment manufacturing industry. Economic Survey. 25(5), 43-45 (2008)

[9] Chen Aizhen, Liu Zhibiao: Determinants of Chinese machinery industries' position in GVCs: based on input-output empirical analysis of divided industries. Journal of International Trade. (4), 115-125 (2011)

[10] Zhou Shenqi, Lan Zhenxian & Fu Hua: A study on the division status of China's manufacturing industry in global value chains - based on Koopman's GVC position indices. Journal of International Trade. (2), 3-12 (2014)

[11] Hatani F.: The logic of spillover interception: the impact of global supply chains in China. Journal of World Business. (44), 158-166 (2009)

[12] Chen Aizhen, Zhong Guoqiang: Does international trade in China's equipment manufacturing industry promote its technology development? Economist. (5), 43-53 (2014)

[13] Liu Qiang: The mechanism effect analysis of transnational corporations' investment to China on industrial security. Science of Science and Management of S&T. 32(12), 86-93 (2011)

[14] Wu Qiang, Liu Zhibiao: Analysis on the market space obstacle of Chinese national equipment manufacturing industry based on the global value chain in downstream industry. China Industrial Economics. (3), 43-55 (2012)

[15] Giuliani E., Pietrobelli C. & Rabellotti R.: Upgrading in global value chains: lessons from Latin American clusters. World Development. 33(4), 549-573 (2005)

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