Social Science and Management
ISSN: 3007-6862
DOI: https://doi.org/10.61784/ssm3046

THE DUAL EFFECTS OF A COUNTRY'S OVERSEAS PATENT NETWORK LAYOUT ON ITS EXPORT: SCALE-UP OR QUALITY IMPROVEMENT

LuoLe Zhou[1], ZuChang Zhong[1*], XiaoMin Liang[2], JunYi Zhang[2], Jing Liu[2]
[1]*Guangdong Institute for International Strategies, Guangdong University of Foreign Studies, Guangzhou 541402, Guangdong, China.*
[2]*School of Business, Guangdong University of Foreign Studies, Guangzhou 510006, Guangdong, China.*
Corresponding Author: ZuChang Zhong, Email: zhongzuc@163.com

Abstract: It is an important measure for a country to consolidate and enhance its international competitiveness by constructing an overseas patent network. In this paper, we study the mechanism and dual effects of a country's overseas patent network on its export performance from the perspectives of the breadth, depth and quality of the network by using the overseas patent data of 60 countries from 2000 to 2018. The main conclusions are as follows: (1) The breadth and depth of overseas patent network and the proportion of the overseas invention patent applications have significant positive influences on a country's export quantity and export quality, while the proportion of patent applications in developed countries is negatively related to export quantity and export quality. (2) The effect of the breadth of overseas patent network on export quantity is "U-shaped", and the effect on export quality is "reversed U-shaped". Besides, the "reversed U-shaped" relationship can also be found between the depth of overseas patent network and export quantity and export quality. We also find that some countries have excessive patent layouts in developed countries. (3) The heterogeneity analysis reveals that differences in types of countries and patents can affect the effects of the overseas patent network. For example, both the breadth of overseas patent network and the proportion of the overseas invention patent applications have greater impacts on export quantity in the developed country than in the developing country, while the effects of the depth of overseas patent network and the proportion of patent applications in developed countries on export quantity and export quality in the developing country are greater than those in the developed country. The study makes a marginal contribution to the existing theories about the impact of the overseas patent network on export performance, and provides some theoretical references for countries, especially developing countries, about adjusting overseas patenting strategies.
Keywords: Breadth of overseas patent network; Depth of overseas patent network; Export quantity; Export quality

1 INTRODUCTION

The flow of innovation factors has greatly contributed to the growth of global patent applications. Statistics from the World Intellectual Property Indicators Report 2024 (WIPI) show that global patent application activity reached a new high in 2023, with the number of applications exceeding 3.5 million for the first time, marking the fourth consecutive year of growth in global patent applications despite the challenging macroeconomic environment. As the world trade and investment links become increasingly close, more and more countries accelerate the pace of overseas patent layout, the complexity of overseas patent network is further strengthened, the coverage is expanded, and the degree of concentration and quality level is also continuously upgraded. However, in terms of the overall scale of overseas patents, there is still a huge difference between developed countries and developing countries, and although China has jumped to the first place in the world in terms of the number of PCT patents applied, the proportion of overseas patent applications is still only 6.7%, far lower than that of developed countries such as Germany with 59.4%, Japan with 46.3%, and the United States with 45.6%, etc. The total amount of overseas patent application of the United States is 2.3 times of that of China. For different economies, the overseas patent layout of developed countries is becoming more and more perfect, and the main purpose of their overseas patent strategy is to consolidate and enhance the advantages of the existing patent network and expand more target markets, so as to be able to form a more diversified patent network advantages. Most developing countries are still in the initial stage of overseas patent layout, while large developing countries such as China and India are accelerating their overseas patent layout in an all-round way in order to form a global patent network advantage. Overseas patents reflect the degree of recognition of the importing country for the products or technologies of the home country, which is a measure of the innovation ability of the home country and an important weapon to gain competitive advantage in exports [1]. Therefore, it will be of great theoretical and practical significance to explore the mechanism and multiple influence effects of overseas patent network layout on a country's export.

Identifying the internal dynamics of a country's exports plays a crucial role in its economic development[2]. Previous studies have focused on the factors influencing export size and export technological complexity. At the micro subject level, outward foreign direct investment expands the depth margin and breadth margin of exports, thus affecting the technological complexity of firms' export products[3]; at the macro subject level, technological intensity drives a country's export growth by affecting efficiency[4], and FDI, institutional quality, intellectual capital, and infrastructure

are also export quality key factors for the improvement of export quality[5-7]. Many scholars have explored the influencing factors of exports from the perspectives of different subjects, such as institutional quality, economic conditions, and intellectual capital.

Closer global trade linkages have led to more business opportunities and risks of imitation, prompting knowledge owners to seek knowledge or technology protection abroad, which has facilitated the diffusion of innovations globally and contributed significantly to the growth of the world economy[8-10]. Studies have examined the relationship between innovation and export trade, using the number of patents as the main indicator of technological output. Zhou et al. used the number of patent applications as a proxy variable for innovation performance, and elucidated the mechanism of the impact of export trade of listed companies on corporate innovation from the perspectives of economies of scale and risk-taking. Other scholars explored the innovation value of patents from different sources [11]. Yu Daoxian and Liu Haiyun differentiated between the number of domestic patents granted and the number of foreign patents granted to study the impact of technological innovations from different sources on China's export trade, and found that technological innovations from foreign countries had a stronger promotion effect on China's export trade [12]. Ozsoy et al. (2021) also found that patent applications from foreign countries promoted the technological sophistication of the host country's exports. Other studies used the filing or granting of patents abroad as a measure of a country's innovative capacity [13].Blind and Jungmittag used the number of patents filed by Germany at the European Patent Office as a technological indicator of innovation and standards, and found that Germany's innovative capacity explains its export performance [14].Chen using the number of patents granted in the US as a technical indicator, examined the marginal export effect of innovation in manufacturing industries in 105 countries [15]. The results showed that innovation affects export performance mainly along the intensive margin. Compared with domestic patents, overseas patents better reflect the degree of recognition of home country innovations in the host market and are more suitable for the study of export trade issues.

Most studies have explored the impact of the innovation value of patents on export trade, but the complexity and structure of patent networks have received little attention, and there is a paucity of research based on the breadth, depth and quality perspectives of patent networks. The impact of the characteristics of a country's overseas patent network layout on exports, as the main body of patent layout, is also generally ignored. Among the existing studies, Cai Zhonghua et al. constructed a similarity index, pointing out the relationship between China's patent layout in the 'Belt and Road' countries and the structure of exports, but did not explore the mechanism of the impact of overseas patent network layout on exports [16]. Li Jieyu et al. explored the dual effect of product innovation and process innovation of overseas patents by investigating the performance of overseas patents of various countries in the U.S. market [1]. Willoughby pointed out that there is a causal relationship between the behavior of foreign international patent applications and domestic economic development, but the internal mechanism of the relationship is not clear [17].

Does the construction of overseas patent networks contribute to the growth of a country's export quantity, or does it improve the quality of a country's exports, or does it have both effects and which one is dominant? What are the differences in the impact of the breadth and depth of patent networks on the quantity and quality of a country's exports? What are the differences between the export effects of patenting in developed countries and those in developing countries? Is there a problem of over-layout in developed countries? The answers to these questions are particularly important for developing countries that are accelerating their overseas patent deployment. The marginal contribution of this paper is mainly in the following aspects: (1) putting the breadth, depth and quality dimensions under a unified analytical framework, exploring the dual impact of the structural characteristics of overseas patent networks on the quantity and quality of a country's exports, and expanding the existing research results on the impact of overseas patent network layout on exports. (2) Explore the non-linear relationship between the breadth, depth and quality of overseas patent networks on the quantity and quality of exports, and clarify the intrinsic mechanism between the layout of overseas patent networks and exports. (3) Examining the heterogeneity of different types of countries and different types of patent layouts to further deepen the understanding of the mechanism of the effect of the breadth and depth of overseas patent networks on exports.

2 THEORETICAL MECHANISMS AND HYPOTHESES

It has been shown that there is a significant positive correlation between technological performance represented by patents and export performance represented by export market share[18]. So how would the characteristics of a country's overseas patent network affect the quantity and quality of its exports? What are the underlying mechanisms? In the following paper, we will specifically discuss the mechanism of the breadth and depth of overseas patents on the quantity and quality of exports respectively.

2.1 Theoretical Mechanism of the Breadth of Overseas Patent Networks on Export Quantity and Export Quality

Technical barriers to trade have gradually developed into one of the means of trade protection in many countries[19], and overseas patents can, to a certain extent, alleviate the impact of patent barriers such as technical barriers and market access on trade[20]. Overseas patents are the 'entry ticket' for a country to enter the overseas market, but also a way to compete for market share and obtain high profits. In the highly competitive international market, for a country, the wider the overseas patent network means that the country legally holds the relevant patents in more countries, the smoother the country will enter more overseas markets, which will help to broaden the sales channels of export products

and increase the country's export scale. At the same time, according to the new trade theory, when the size of the export market increases, the productivity of the whole industry will be increased accordingly due to the reallocation of resources. This means that after a country succeeds in joining overseas markets and broadening its export scale, it can greatly increase its risk-taking by learning and making full use of the host country's knowledge, experience, technology and other factors. Risk-taking can promote firm innovation[21-22] and increase the level of technology and productivity in the home country. As productivity increases, the marginal cost of export products decreases and the quality rises[23-24], which in turn enhances export stability and improves export competitiveness[25].

However, the positive effect of the breadth of overseas patent networks on the quantity of exports may have a threshold effect, which means the effect of the breadth of overseas patent networks on the quantity of exports of a country may not be significant when the country holds patents in only a few countries. Firstly, the home country has fewer international markets to expand because of its patent holdings, and fewer intangible assets such as knowledge and experience that can be learnt and acquired in the new market environment. At the same time, the degree of coupling between the knowledge and other intangible assets extracted from different regions may be lower, and the resources acquired by the home country are more different. If the home country wants to make real use of the acquired resources, it will take a certain amount of time and capital investment, and the cost of adopting new knowledge and new technologies will also weaken the advantages brought by the breadth effect of overseas patent networks. In addition, due to the acquisition of fewer intangible assets, the change in the level of technology in the home country is not obvious, and the increase in productivity is not significant. However, when the breadth of overseas patent network reaches a certain amount, the positive effect of patent breadth on the number of exports will become more obvious. Firstly, as the breadth of overseas patent layout increases, the home country acquires more resources from the host country, the coupling of resources will gradually increase, the accumulation of related knowledge leads to similar innovations, and it is easier to realize the transfer and integration of technology[26] , and the marginal cost required to be spent on integrating the new knowledge and new resources will be gradually reduced, and at this time, the overseas patent network breadth brings the advantage of reducing production costs will also be more obvious. In addition, the more patents a country holds and the more overseas markets it enters, the more international competition the home country will face. In order to increase its advantage in international competition, the risks associated with fierce competition will also stimulate technological innovation[11], which will help to produce products of better quality[27], as well as increase productivity to reduce production costs, thus increasing the number of exports from the home country. Therefore, there may be a threshold effect of overseas patent network breadth on the number of exports, and the positive effect of patent breadth on the number of exports will become more and more obvious only when the breadth of overseas patent network reaches a certain number.

In addition, resource fragmentation, increased additional regulatory concerns, and technical barriers may undermine the contribution of improved export product quality from increased breadth of overseas patent networks. On the one hand, when the breadth of a country's overseas patent network becomes wider, the country's overseas market layout becomes wider, and the human and organizational resources of the home country will be dispersed to more overseas markets. This means that as the breadth of the overseas patent network increases, while the home country continues to absorb and assimilate more resources, these resources are gradually dispersed into more shares, and the role of the level of innovation and technology in stimulating the improvement of the quality of export products gradually diminishes. On the other hand, overseas expansion brings more uncertainty in several areas; e.g., the wider the patent network, the more potential competitors or infringers one faces[28], which requires more managerial attention to be invested in controlling risks to cope with these additional uncertainties[29-31], and accordingly the home country's attention and focus on export quality decreases. Moreover, when the technical level of the production products is improved to a certain extent, it is inevitable that technical barriers will be encountered, and it is more difficult to improve product quality, the enthusiasm for technological innovation will be weakened, and the benefits of innovative technology investment will gradually diminish. Therefore, when the Overseas Patent Breadth reaches a certain level, the positive effect of the Overseas Patent Breadth on the quality of exports will gradually diminish.

The mechanism of the Overseas Patent Breadth and the quantity and quality of exports is shown in Figure 1:

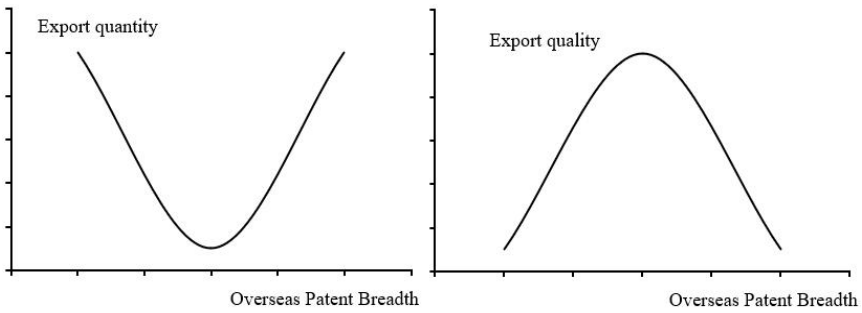

Figure 1 Mechanism of the Overseas Patent Breadth

This paper proposes:

Hypothesis 1: The relationship between the breadth of overseas patent network and the number of exports is ‘U-shaped’, that is, the number of exports decreases with the increase of the Breadth of overseas patent network, and when it

exceeds a certain threshold, the further increase of the Breadth of overseas patent network positively contributes to the increase of exports quantity.
Hypothesis 2: The relationship between the breadth of overseas patent network and the quality of export is in an 'inverted U-shape', that is, the quality of export improves along with the increase of the breadth of overseas patent network, and when it exceeds a certain threshold, the further increase of the breadth of overseas patent network inhibits the increase of the quality of export.

2.2 Theoretical Mechanisms of the Depth of Overseas Patent Networks Affecting the Quantity and Quality of Exports

The depth of a country's overseas patent network has an incentive effect on the quantity and quality of its exports. The depth of the overseas patent network refers to the number of patents applied for or granted by the home country in the host country. Firstly, deeper depth means that the home country is better able to understand the host country's environment and acquire different local knowledge. Increased familiarity with the local environment weakens the 'outsider disadvantage', which is conducive to the further expansion of the market scale, and also makes it easier for intangible assets such as local knowledge to be digested and integrated[26] , which stimulates the upgrading of the home country's technological level, promotes the improvement of the quality of exported products and reduces the marginal cost of production, and creates economies of scale. Secondly, the improvement of the depth of a country's overseas patent network can avoid encountering patent barriers in terms of industry competition, etc., and can reduce the risk of encountering patent litigation as well as the related compensation, coordination and other costs[20], reduce transaction costs, incentivize the country's export behaviors, and increase investment in innovative technologies.
However, when the depth of a country's overseas patent network reaches a certain value, the incentive effect of patent depth on the quantity and quality of exported products may be constrained. Firstly, when the depth of the overseas patent network of the home country gradually deepens, the level of science and technology and productivity also continue to increase, but when the depth of the overseas patent network reaches a certain value, the production technology of the home country is prone to technical barriers, the incentive to innovate products will be weakened, and the marginal benefit of investment in technological innovation will also be reduced. Secondly, due to the 'self-selection' effect[32], some of the higher productivity enterprises in the home country will give up exporting and choose outward foreign direct investment[33], and the export scale of the home country will be affected. Thirdly, there is a level of technological spillover from the home country's product technology in the process of overseas trade, which will play a role in demonstrating, stimulating and promoting technological innovation for the host country's competing enterprises in the same industry [34], resulting in the effect of technological diffusion and the effect of 'learning by doing', and to a certain extent, it will give competitors more opportunities to learn or imitate, and even some other exporting countries can improve the quality of their own export products by obtaining innovation benefits through 'learning from exporting' [35] , which will lead to the weakening of the value of the home country's export products and the reduction of the competitiveness of export products, which is unfavorable to the home country's product export trade. Fourth, with the deepening of a country's overseas patent network, it may form a monopoly in the host country, which is unfavorable to the exports of other prospective exporters[36] and impedes the free competition in the local market, at which time the relevant enterprises in the home country are susceptible to the suppression of the local government or relevant industries. At the same time, due to the monopoly effect, the home country's innovation enthusiasm will be weakened, the investment in technological upgrading and transformation will be reduced, which is not conducive to the export behavior of the home country and the further improvement of the technological level.
The benefit function of overseas patent depth is convex, as the depth of overseas patents increases, the degree of familiarity with the local area increases, the 'outsider's disadvantage' is weakened, and the home country's access to local knowledge and other resources increases. However, the benefit of patent depth has a certain limit, when the depth reaches a certain value, the home country completely internalized the host country's market resources as well as the knowledge gained from competitors, the increase in benefits will tend to converge[26]. The cost function of overseas patent depth is concave, with the increase of overseas patent depth, the patent rights will overlap with each other, and it is easy to form the phenomenon of 'patent jungle', and the intricate dependence relationship between patents will increase the cost of patent implementation[37]. The mechanism of the depth of overseas patent network and export quantity and quality is shown in Figure 2:

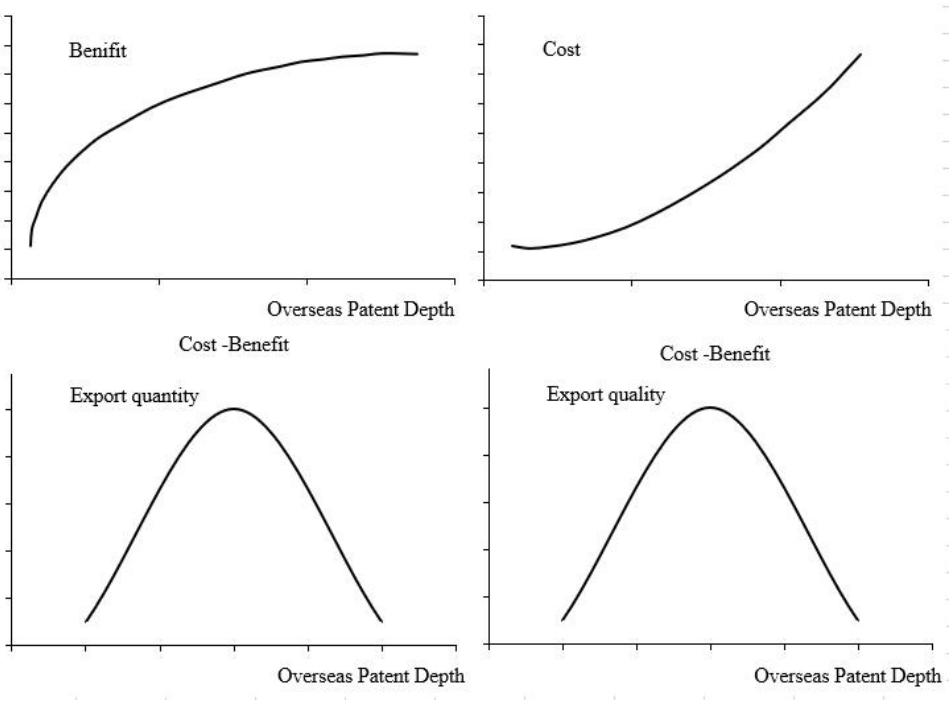

Figure 2 Mechanism of the Role of Depth of Overseas Patent Network

This paper puts forward the following hypothesis:
Hypothesis 3: The relationship between the depth of overseas patents and the quantity and quality of exports is in an inverted 'U-shape', which means the quantity and quality of exports increase and improve along with the increase in the depth of overseas patents, and when a certain threshold is exceeded, the further increase in the depth of overseas patents inhibits the increase in the quantity of exports and the improvement of the quality of exports.

3 VARIABLE MEASUREMENT AND DATA SOURCES

3.1 Measurement of Variables

3.1.1 Measurement of export quantity and export quality indicators

The explanatory variables in this paper are export quantity and export quality, export quantity (EXW) is expressed by the export value, the unit is 1 billion US dollars; export quality (EXQ) is expressed by the export technological complexity TSI, this paper draws on the measurement method of Lall et al. (2006) [38], Rodrik (2006) [39], a country's export technological complexity specific calculation process is as follows:
Firstly, the technical complexity of a country's exports of a product g is calculated by using equation (1). Using equation (2) to calculate the export technical complexity of each country, the specific formula is as follows:

$$PRODY_g = \sum_c \frac{(x_{cg}/X_c)}{\sum_c (x_{cg}/X_c)} PGDP_c \tag{1}$$

$$\mathrm{TSI}_{it} = \sum_g \left(\frac{x_{cg}}{X_c}\right) \cdot PRODY_g \tag{2}$$

where, denotes exports of country c product g, is country c's total exports, is country c's gdp per capita in constant 2011 US dollars and purchasing power parity, in US dollars, denotes country c's exports of product g, is country c's exports, and exports are all expressed in US dollars.

3.1.2 Measurement of indicators of the breadth, depth and quality of overseas patent networks

The explanatory variables in this paper include overseas patent network breadth, depth and quality. Overseas Patent Network breadth (GD) is constructed by using the number of countries that are the target of a country's overseas patent applications, and the larger the number of countries that are the target of applications, the wider the scope of overseas patent layout. Overseas Patent Network Depth (SD) is expressed as the ratio of a country's total number of overseas patent applications to its breadth, and is used to describe the average level of overseas patent applications among host countries. Meanwhile, in order to examine the impact of different types of overseas patent network layouts on exports, i.e., the impact of the breadth and depth of overseas invention patent networks, utility model patent networks and design patent networks on the quantity and quality of exports, this paper also measures the breadth and depth indicators of the

three types of overseas patent networks. Compared with utility model patents and design patents, invention patents have a higher degree of innovation, so this paper constructs the proportion of overseas invention patent applications (IPP) indicator as an indicator of the quality of a country's overseas patent network. The larger the proportion of overseas invention patents, the higher the quality of the patent network. At the same time, this paper also measures the proportion of developed countries in the target countries of overseas patent applications (PDC) as an indicator to describe the quality of overseas patent network, the higher the proportion of patent layout in developed countries, the higher the quality of overseas patent network.

3.1.3 Control variables measurement

By combing through the relevant literature, this paper selects the following indicators as control variables: resource endowment, foreign direct investment, the level of outward foreign direct investment, the level of technology and the level of education expenditure. The specific indicators are described as follows:

(1) Resource endowment (RES): the richer a country's resources are, the more favorable it is to the increase of export scale, which also has an impact on export quality. In this paper, the share of fuel and mineral exports in product exports is used to indicate a country's resource endowment.

(2) Foreign direct investment (FDI): the higher the level of foreign investment attraction, the more favorable to the growth of a country's export scale, and the level of export quality will be improved through technological spillovers. In this paper, the net inflow of FDI as a proportion of GDP is used to indicate the level of a country's attraction of foreign investment.

(3) The level of outward foreign direct investment (OFDI): the higher the level of OFDI, the stronger the competitive advantage of a country's market players in the host market, which is conducive to the enhancement of export quantity and quality. This paper adopts the net outflow of OFDI as a proportion of GDP to indicate the level of OFDI of a country.

(4) Technology level (TE): technology level is one of the important factors affecting the quantity and quality of exports. This paper adopts the proportion of high-tech product exports to manufactured exports to indicate a country's technology level.

(5) The level of education expenditure (EDUE): a country's increased investment in education helps to improve the level of human capital and innovation capacity, thereby increasing the quantity and quality of exports. In this paper, the total public expenditure on education as a proportion of government expenditure is used to express a country's education expenditure level.

3.2 Sample data sources

In this paper, overseas patent data and development indicator data of 60 countries in the world from 2000 to 2018 were selected. The patent data come from the World Intellectual Property Organization (WIPO), and include the application and granting of a country's invention, utility model and design patents overseas. Data on export quantities and control variables are from the World Bank Development Indicators database, and data on relevant indicators measuring export quality are from the UN COMTRADE database, using data on export products classified according to the United Nations Standard International Trade Classification Statistical Database (UNSITC) and the HS code classification, using the three-digit code classification according to SITC Rev.2. In the selection of sample countries, The initial sample for this paper was selected from the OECD-TIVA database of 66 countries, due to the limited effect of the layout of the overseas patent network is too small on the export, so this paper excludes the countries with too few overseas patent applications and the number of host countries oriented to the host country is too small, considering the availability and completeness of data on control variables, a final sample of 60 countries from 2000-2018 was selected. The sample covers OECD, EU, G20 countries, East Asian and Southeast Asian economies and South American countries, and the overseas patent applications of these countries account for more than 90% of the global PCT patent applications, so the sample has a good representation.

3.3 Descriptive Statistics of Variables

The descriptive statistics of the main variables are shown in Table 1. From the perspective of overseas patent network layout, the mean value of depth is 159.06, the median value is 21.54, and the difference between the maximum value and the minimum value is large, which indicates that the depth of overseas patent network varies greatly among the countries in the sample, and only a few of them have a greater depth of overseas patent network. The mean value of breadth is 43.07, the median value is 40, and the difference between the maximum and minimum values is also large. In terms of export quantity and export quality, there are large differences in export size and export quality between countries. The mean value of the share of patent applications in developed countries reaches 0.726, indicating that most countries have located their overseas patents in developed countries.

Table 1 Descriptive Statistics of the Main Variables

Variable	Mean	Median	Maximum	Minimum	standard deviation	skewness	kurtosis

EXW	193.60	76.04	2486.70	0.84	315.11	3.51	18.47
EXQ	23320.87	23493.79	48354.4	10011.88	4975.233	0.17151	4.149189
GD	43.07	40.00	122.00	0.00	28.12	0.42	2.37
SD	159.06	21.54	2924.43	0.00	404.43	4.36	23.44
IPP	0.71	0.79	1.00	0.00	0.22	-1.18	4.00
PDC	0.72	0.74	1.00	0.00	0.16	-2.03	9.62
RESOURSE	19.77	10.19	97.90	0.00	22.44	1.78	5.37
FDI	7.64	3.14	449.08	-58.32	27.05	10.23	131.93
EDUE	13.85	13.17	31.37	5.30	4.09	1.08	4.60
TE	17.27	13.38	90.02	0.00	13.84	1.60	5.94
OFDI	5.34	1.45	301.25	-87.23	23.69	7.18	73.76

4 EMPIRICAL ANALYSIS

4.1 Model Design

This paper tests the mechanism and effect of overseas patent network on export quantity and export quality by introducing an econometric model to test the mechanism and effect of overseas patent network on export quantity and export quality from the perspectives of breadth, depth and quality, and the benchmark model is as follows:

$$\mathrm{EXW_{it}}/EXQ_{it} = \alpha_0 + \alpha_1 GD_{it} + \alpha_2 SD_{it} + \alpha_3 IPP_{it} + \alpha_4 PDC_{it} + \Phi X_{it} + \varepsilon_{it} \quad (3)$$

Where and stand for country and year, EXW and EXQ denote a country's export quantity and export quality respectively, GD and SD denote the breadth and depth of overseas patent network respectively, IPP and PDC denote the quality of overseas patent network, and X is a collection of control variables including variables such as the level of resource endowment, the level of education expenditure, foreign direct investment (FDI), outward foreign direct investment (OFDI), and the level of technology. Meanwhile, in order to test the non-linear effects of the breadth, depth and quality of overseas patent networks on the quantity and quality of exports, we introduce the squared terms of the breadth, depth and quality variables on the basis of the benchmark model. The specific non-linear model is as follows:

$$\mathrm{EXW_{it}}/EXQ_{it} = \alpha_0 + \alpha_1 GD_{it} + \alpha_2 {GD_{it}}^2 + \alpha_3 SD_{it} + \alpha_4 {SD_{it}}^2 + \alpha_5 IPP_{it} + \alpha_6 PDC_{it} + \alpha_7 PDC_{it}^2 + \Phi X_{it} + \varepsilon_{it} \quad (4)$$

4.2 Benchmark Regression Analysis

The results of the benchmark regression are shown in Table 2, in which columns (1)-(4) report the regression results of export quantity on the breadth and depth of overseas patent network, the share of overseas invention patent applications, and the share of overseas patent applications in developed countries, respectively; columns (5)-(8) report the regression results of export quality on the breadth and depth of overseas patent network, the share of overseas invention patent applications, and the share of overseas patent applications in developed countries, respectively. The regression results in Columns (1)-(3) show that the breadth and depth of overseas patent networks, and the share of overseas invention patent applications have a significant positive effect on the quantity of exports. Controlling for other variables, in terms of the export effect of the overseas patent network, for every unit increase in the breadth of the overseas patent network, the country's exports will increase by 3.5785 units; for every unit increase in the depth of the overseas patents, the country's exports will increase by 0.3037 units; and for every unit increase in the share of patent applications for inventions abroad, the country's exports will increase by 94.1468 units. And the regression result of Column (4) indicates that the proportion of overseas patent applications in developed countries has a significant negative effect on the number of exports, which indicates that the more the proportion of overseas patent applications in developed countries is increased, the more it will inhibit the number of exports of the country. The reason may be that the proportion of overseas patent applications in developed countries is too high in most of the countries, and at this time, the cost effect and the competition effect brought by the strategy of overseas patent layout inhibit the quality of its technological innovation. the quality of their technological innovation[40], which is not conducive to further expanding the export scale of products.

The regression results in columns (5)-(7) show that the breadth and depth of overseas patents and the share of overseas invention patent applications have a significant positive effect on export quality. Each unit increase in the breadth and depth of overseas patents and the share of overseas invention patent applications corresponds to an increase in the country's export quality by 93.5052, 1.9476 and 2852.8980 units, respectively. While the regression results in column (8) illustrate that the share of overseas patent applications in developed countries has no significant effect on the quality of exports, which indicates that a change in the share of overseas patent applications in developed countries will not have an impact on the quality of a country's exports. Some studies have shown that for professional-intensive enterprises, the improvement of patent quality is only achieved by increasing the variety of exported products[41] , but not at the same time improving the quality of exported products. Therefore, when the proportion of overseas patent applications is high in developed countries, this patent quality indicator may not have an impact on the quality of export products.

Combined with the theoretical analysis in the previous section, the results of the benchmark regression show that the

overseas patent network promotes the enhancement of a country's export quantity and the improvement of export quality, and the breadth, depth and quality of the overseas patent network mainly show positive competitive and learning effects, leading to the improvement of productivity and technological level, and the decrease of production costs, so that the improvement of the breadth and depth of the overseas patent layout significantly increases the quantity of exports and improves the quality of exports.

Table 2 Impact of Overseas Patent Network Layout on Export Quantity and Export Quality

Variable	Export Quantity				Export quality			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	-5.842*** (8.400)	78.514*** (8.311)	85.872*** (9.654)	177.460*** (17.139)	17245.24*** (470.326)	24393.89*** (433.468)	23518.44*** (763.088)	25613.91*** (1054.57)
GD	3.579*** (0.271)				93.505*** (3.365)			
SD		0.304*** (0.011)				1.948***(0.281)		
IPP			94.147*** (13.070)				2852.898*** (410.419)	
PDC				-36.275** (16.595)				-440.594 (647.116)
RES	0.9085*** (0.114)	0.6674*** (0.0657)	0.2079 (0.1320)	0.2229** (0.1094)	436.4806*** (5.7536)	12.31325* (6.5381)	3.6849 (9.1654)	7.9766 (10.1820)
FDI	-0.7607 ** (0.311)	-1.2549*** (0.3314)	-1.341*** (0.3976)	-1.7278*** (0.2991)	21.6841** (9.7640)	-8.5905 (7.7494)	-8.0735 (5.6805)	-13.7518** (6.1473)
EDUE	-1.0133** (0.419)	-3.3475*** (0.3551)	-6.574*** (0.7996)	-6.0627*** (0.5666)	-77.8269*** (27.32730)	-287.779*** (30.4587)	-338.799*** (26.3879)	-335.079*** (22.9903)
TE	1.9324***(0.237)	2.2956*** (0.2480)	2.6369*** (0.2535)	2.7008*** (0.2088)	127.5718*** (8.9089)	125.3817*** (10.9763)	122.3641*** (7.8224)	130.4418*** (8.1995)
OFDI	0.4065** (0.199)	1.0153*** (0.1786)	1.0252*** (0.2191)	1.1991*** (0.2997)	-13.5277 (9.2882)	18.6188 *** (6.7933)	19.2940** (6.3952)	21.5466*** (6.8403)
Country &	yes	yes	yes	yes	yes	yes	yes	yes
R2	0.6253	0.4995	0.2072	0.2995	0.5896	0.2582	0.2560	0.2383
F	220.017***	131.544***	34.46***	56.362***	189.4011***	45.8808***	45.3592***	41.2486***
N	798	798	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

4.3 Nonlinear discussion

In order to examine the non-linear relationship between the layout of overseas patent networks and the quantity and quality of a country's exports, we introduce the squared terms of the breadth, depth and quality variables on the basis of the baseline model. Columns (1)-(3) of Table 3 report the results of non-linear regression of the quantity of exports on the breadth and depth of overseas patent networks versus the share of overseas patent applications that are located in developed countries respectively, and Columns (4), and (5) report the results of the non-linear regression results of export quality on the breadth and depth of overseas patent networks and the share of overseas patent applications in developed countries, respectively.

As can be seen in column (1) of Table 3, in the nonlinear model of overseas patent network breadth and export quantity, the coefficients of the primary and square terms of overseas patent network breadth are negative and positive respectively, and pass the significance test of 1%, which indicates that the effect of overseas patent network breadth on the number of exports is in a 'U-shape' in line with the theoretical expectation, which is similar to the results of Yang,

Zheng et al.[42]. Roughly estimated, the inflection point of overseas patent network breadth is 8.64, i.e. the positive effect starts to appear when the overseas patent network breadth reaches 8.64. The mean value of overseas patent network breadth is 41.32, which is located on the right side of the inflection point, and it can be seen that improving the layout of overseas patent network breadth helps to increase the number of exports, which again verifies the estimation results in Table 1. At the same time, it also shows that there is a limiting value for the positive effect of overseas patent network breadth on the number of exports, when a country's overseas patent network is in more than 8.64 countries, more and more resource accumulation and technological integration and innovation will make the positive effect of patent breadth on the number of exports gradually appear, thus hypothesis 1 is established. The results in column (4) of Table 3 show that there is an 'inverted U-shaped' relationship between the breadth of overseas patent network and export quality, with the inflection point at about 176.90, and the mean level of the breadth of overseas patent network is located to the left of the inflection point. This indicates that increasing the breadth of overseas patent layout is conducive to improving the quality of domestic exports, but when a country's overseas patent network exceeds the threshold, continuing to increase the breadth of overseas patent network may inhibit the improvement of domestic export quality due to the dispersal of resources, the increase in the cost of additional management attention, technical barriers and other problems, which proves that hypothesis 2 is valid.

The regression results in columns (2) and (5) of Table 3 show that there is an 'inverted U-shaped' relationship between the depth of overseas patents and the quantity and quality of exports, with the inflection points at about 2034.75 and 1575.58, respectively, and the mean level of the depth of overseas patents is located on the left side of the inflection points of the two models. This indicates that increasing the depth of overseas patents is conducive to improving the quantity and quality of domestic exports, but when the average number of patents in each country of a country's overseas patent network exceeds 2034.75 or 1575.58, continuing to increase the depth of the overseas patent network may result in a decrease in the quantity and quality of domestic exports due to factors such as technological barriers, self-selection, technology spillover, monopoly effects, and so on. Therefore, hypothesis 3 is valid. Table 3, column (3), column (6) of the regression results show that the proportion of overseas patent applications in developed countries and the number of exports, export quality, there is an 'inverted U-shaped' relationship, and the inflection point of about 0.54, respectively, 0.59; overseas patent applications in developed countries in the proportion of the mean value of 0.73. This shows that whether it is related to the quantity of export or the quality of export, the proportion of overseas patent applications in developed countries is located on the right side of the inflection point, and it is not conducive to the promotion of domestic exports to continue to increase the layout of overseas patent applications in developed countries, which indicates that the layout of overseas patents in developed countries in many countries is excessive and may inhibit the strategy of the layout of overseas patents in developed countries due to the increase in costs, fierce competition and other reasons, which again confirms the empirical results in Table 2.

Table 3 Non-Linear Relationship between Overseas Patent Network Layout and Export Quantity and Export Quality

Variable	Export Quantity			Export quality		
	(1)	(2)	(3)	(4)	(5)	(6)
Cons	36.795*** (6.496)	46.024*** (5.455)	64.416*** (11.557)	16131.710*** (618.648)	23538.850*** (837.239)	16531.840*** (642.635)
GD	-0.745*** (0.187)			135.895*** (13.040)		
GD^2	0.043*** (0.003)			-0.384*** (0.119)		
SD		0.814*** (0.027)			7.878*** (0.982)	
SD^2		-0.00022*** (0.00001)			-0.003*** (0.0004)	
PDC			499.942*** (51.180)			33883.000*** (3069.449)
PDC^2			-462.281*** (49.234)			-28951.060*** (2636.917)
RES	0.9632*** (0.0744)	0.8229*** (0.0633)	0.2131 (0.1298)	37.2968*** (7.8983)	13.1423 (9.5951)	9.0393 (10.5764)
FDI	-0.8645*** (0.2425)	-0.8958*** (0.2356)	-1.6072*** (0.4489)	23.3366** (10.1215)	-2.6879 (6.2181)	-10.3180 (6.4108)
EDUE	-3.1550*** (0.4391)	-2.5572*** (0.3291)	-7.4339*** (0.8042)	-55.0232*** (20.7203)	-246.9012*** (23.1926)	-338.5320*** (28.6551)
TE	2.2102***(0.2301)	1.8445*** (0.1863)	2.4626*** (0.2270)	127.5635*** (7.7105)	118.8433*** (8.3900)	135.2535*** (9.7817)
OFDI	0.6714*** (0.1737)	0.7745*** (0.1287)	1.1649*** (0.2663)	-16.2471* (9.3891)	14.7295*** (5.6594)	16.3903** (7.2295)
Country & year	yes	yes	yes	yes	yes	yes
R2	0.6043	0.5820	0.3241	0.5892	0.3316	0.3408

F	172.3837***	157.1073***	54.1178***	161.8405***	55.9846***	58.3341***
N	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

4.4 Endogeneity and robustness analysis

4.4.1 Endogeneity test

The four indicators of overseas patent layout may not be strictly exogenous, and it is difficult to exclude the existence of endogeneity problems such as omitted variables. The lag one period of the endogenous variable has a strong correlation with the endogenous variable and no significant correlation with the error term, which meets the conditions of the existence of a significant correlation between the instrumental variable and the endogenous variable and the exogeneity of the instrumental variable, and it is considered to be a valid instrumental variable[43], so this paper adopts the lag one period of the breadth, depth, and quality variables of the overseas patent network as the instrumental variable respectively Endogeneity regression was conducted, and the specific results are shown in Table 4.

For the impact of overseas patent layout on the number of exports, the instrumental variable regression results after considering endogeneity show that the coefficients of the impact of the breadth and depth of overseas patent network and the share of patent applications for inventions filed overseas on the number of exports are still robustly positive, and the absolute values of the coefficients of the breadth and the share of patent applications filed for inventions filed overseas have increased compared with those of the baseline regression, which suggests that the positive impact of the breadth of overseas patent network and the share of patent applications for inventions filed overseas on the number of exports may be underestimated if endogeneity issues are not controlled. In addition, for the effect of overseas patent layout on export quality, after considering the endogeneity problem, the instrumental regression results show that the results of overseas patent network breadth, depth and the share of overseas invention patent applications on export quality are still robustly positive, but the effect values of overseas patent network breadth and depth have decreased compared with the baseline regression, and the effect value of the share of overseas invention patents has increased.

Table 4 One Period Lagged Instrumental Variables Regression

Variable	Export Quantity				Export quality			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	-70.744*** (11.215)	84.749*** (8.275)	88.176*** (34.3007)	187.997* (98.73)	17817.95*** (791.291)	24859.14*** (753.055)	23768.47*** (779.879)	23512.88*** (1040.710)
GD	4.222*** (0.350)				89.896*** (6.309)			
SD		0.300*** (0.011)				1.765***(0.238)		
IPP			108.310*** (28.979)				3012.061*** (419.365)	
PDC				38.533 (72.06)				1213.515 (897.237)
RES	0.9568*** (0.1254)	0.6441*** (0.074)	0.2338 (0.4285)	0.1281 (0.558)	32.7806*** (8.7473)	9.0489 (10.7993)	1.0778 (9.9768)	6.4941 (9.6754)
FDI	-0.7874** (0.3434)	-1.294*** (0.338)	-1.3505*** (0.303)	-2.1004** (0.831)	17.9907* (9.31)	-10.3479* (5.5259)	-8.8316 (5.5434)	-12.0182*** (4.6173)
EDUE	-1.7403*** (0.4635)	-3.65*** (0.348)	-7.4023*** (1.963)	-9.6195** (4.012)	-96.1451*** (17.6589)	-308.746*** (21.5937)	-354.247*** (25.9801)	-256.178*** (31.8120)
TE	2.4851(0.3088)	2.4621*** (0.255)	2.8613*** (0.4668)	2.3999** (1.194)	133.6369*** (6.1877)	134.5443*** (7.2377)	130.9423*** (6.3959)	136.5868*** (12.6129)
OFDI	0.3094 (0.2348)	1.0309** (0.19)	1.0083*** (0.2973)	2.0841** (1.036)	-10.6599 (8.9942)	18.6651*** (5.8063)	18.7072*** (6.1825)	21.3055*** (5.2754)
Country &	yes	yes	yes	yes	yes	yes	yes	yes
R2	0.7881	0.4931	0.2351	0.0840	0.5883	0.2859	0.2796	0.1872
F	465.49***	121.77*** *	38.4725*** *	11.479*** *	178.8309*** *	50.1029***	48.5892***	28.8243***

N	758	758	758	758	758	758	758	758

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

4.4.2 Robustness test

Considering the impact of other factors on the regression estimation results of this paper, we will further conduct a robustness test of the empirical model. The three ways of testing are considered in the robustness test: lagging the explanatory variables by one period, replacing the explanatory variables and replacing the explanatory variables, and the results are shown in Tables 5-7 below.

Firstly, the method of regressing the lagged one period of the explanatory variables using the quantity of exports and the quality of exports respectively. By comparing the results of the benchmark regression (Table 2) with the results of the lagged one-period regression (Table 5), it can be found that the effects of the breadth and depth of the overseas patent network and the proportion of patent applications for inventions abroad on the quantity and quality of exports are basically the same as those above, i.e., the breadth and depth of the overseas patent network and the proportion of patent applications for inventions abroad have a promotional effect on the quantity and quality of exports.

Variable	Export Quantity				Export quality			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	-64.553*** (13.923)	83.678*** *	104.749*** *	177.237*** *	18466.79*** *	24792.43*** *	24071.83*** *	26100.69*** *
GD(-1)	4.160*** (0.366)				84.635*** (5.955)			
SD(-1)		0.310*** (0.011)				1.905*** (0.270)		
IPP(-1)			86.903*** (12.696)				2636.138*** *	
PDC(-1)				-21.900 (16.880)				-589.873 (900.386)
RES	1.0032*** (0.113)	0.6439*** * (0.072)	0.2296 (0.1468)	0.2134* (0.1137)	30.2253*** (8.8372)	9.1209 (10.7983)	1.4214 (10.1769)	5.9033 (6.7272)
FDI	-0.865** (0.364)	-1.292*** (0.335)	-1.4124*** (0.4699)	-1.7629 (0.3107)	11.3330 (7.1986)	-10.1517* (5.5609)	-5.7230 (5.8054)	-14.9078 (11.1857)
EDUE	-1.796*** (0.477)	-3.594*** (0.357)	-7.4199*** (0.7290)	-6.5745*** (0.6166)	-112.786*** (18.9619)	-305.228*** (21.5447)	-356.228*** (25.2582)	-352.42*** (29.2681)
TE	2.5486***(0.297)	2.4705*** * (0.258)	2.8579*** (0.2481)	2.8122*** (0.2118)	134.2523*** * (5.2956)	134.5477*** * (7.2580)	129.452*** (7.0275)	139.2781*** * (10.5696)
OFDI	0.4630** (0.233)	1.0374*** * (0.189)	1.0480*** (0.2694)	1.2401*** (0.3106)	-2.1211 (6.2349)	18.5591*** (5.7812)	15.2671*** (5.8862)	21.0114** (10.0545)
Country	yes	yes	yes	yes	yes	yes	yes	yes
R2	0.7805	0.5009	0.2292	0.3116	0.5493	0.2896	0.2800	0.2681
F	445.04***	125.61*** *	37.2238*** *	56.6426*** *	152.5748*** *	51.0351***	48.6794***	45.8497***
N	758	758	758	758	758	758	758	758

Table 5 Lagged One Period Regression Test Results

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

Secondly, this paper uses the replacement of core explanatory variables to carry out the robustness test. Replacing the application layout of overseas patents with the granting of overseas patents for regression, the results are shown in Table 6. The results show that the breadth (GDA) and depth (SDA) of overseas granted patents and the proportion of overseas invention granted patents (IPAP) have a significant positive effect on the quantity and quality of exports, and the proportion of overseas patents granted in developed countries (PADC) has no significant effect on the quality of exports, which is consistent with the above regression results and test results. However, the significance level of the proportion of overseas patents granted in developed countries on the role of export quantity has changed, and the proportion of overseas patents granted in developed countries has a significant positive effect on export quantity, which means that

the more the proportion of overseas patents granted in developed countries, the higher the quality of the overseas patent layout, and the greater the promotion effect on export quantity.

Table 6 Results of Regression Test for Replacement of Explanatory Variables

Variable	Export Quantity				Export quality			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	-56.810*** (10.711)	77.039*** (8.227)	102.504*** (12.379)	169.81*** (26.57)	17764.94*** (745.538)	24270.39*** (422.526)	23743.01*** (887.820)	23905.01*** (686.288)
GDA	4.126*** (0.318)				90.122*** (5.304)			
SDA		0.522*** (0.016)				3.707***(0.567)		
IPAP			70.953*** (11.817)				2951.665*** (664.423)	
PADC				59.219*** (20.62)				249.348 (808.317)
RES	0.9949*** (0.1063)	0.7215*** (0.0643)	0.2770** (0.1365)	0.1433 (0.133)	35.8628*** (8.1424)	13.0030* (6.8442)	0.6789 (10.2966)	6.5984 (8.7008)
FDI	-0.798*** (0.2902)	-1.246*** (0.3166)	-1.4692*** (0.4681)	-2.09*** (0.609)	19.7770* (10.5691)	-8.3962 (10.8623)	-5.5066 (6.1316)	-11.0713 (10.0331)
EDUE	-0.6799* (0.4084)	-3.332*** (0.3570)	-6.1196*** (0.7439)	-9.026*** (1.451)	-73.1860*** (20.2550)	-282.66*** (29.8270)	-319.858*** (31.2893)	-245.167*** (35.6691)
TE	2.0340***(0.2402)	2.2765*** (0.2400)	2.8183*** (0.2364)	2.2741*** (0.288)	125.8141*** (7.3187)	126.0110*** (10.3916)	119.2952*** (7.0180)	131.3269*** (14.0874)
OFDI	0.4344** (0.1930)	1.0344*** (0.169)	1.1097*** (0.2690)	2.0899*** (0.404)	-10.5659 (9.8120)	18.5331*** (9.7115)	16.4989*** (6.2574)	21.5255** (10.0556)
Country &	yes	yes	yes	yes	yes	yes	yes	yes
R2	0.7691	0.5031	0.2181	0.0865	0.5540	0.2631	0.2738	0.1755
F	439.11***	133.462***	36.7719***	12.482***	163.7798***	47.0679***	49.7082***	28.0588***
N	798	798	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

Finally, this paper uses a country's position in the division of labor in the global value chain as a proxy indicator of a country's export quality to conduct a regression [44], and the results of the study indirectly verify the stability of the basic regression and the non-linear model, and the results are shown in Table 7. Columns (1)-Column (4) of Table 7 are the regressions of global value chain division of labor position on the four indicators of overseas patent network layout, and Columns (5) - (7) of Table 7 are the regressions of global value chain division of labor position on the three indicators of overseas patent layout and their quadratic terms, respectively. The results show that the effects of overseas patent network breadth, depth, the proportion of overseas invention patent applications and the proportion of overseas patent applications in developed countries on GVC embedding are all significantly positive; there is a 'U' shaped relationship between the breadth of overseas patent network and the location of the division of labor in GVCs. Depth and the proportion of overseas patent applications in developed countries have an 'inverted U-shaped' relationship with the location of global value chain division of labor, which is basically consistent with the conclusions of the benchmark regression and the non-linear model, which also indicate that the empirical results of this paper have a strong robustness.

Table 7 Results of Regression Test for Replacement of Explanatory Variables

Variable	position in global value chains						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)

Cons	-0.109*** (0.008)	-0.082*** (0.006)	-0.088*** (0.010)	-0.102*** (0.007)	-0.088*** (0.007)	-0.093*** (0.007)	-0.125*** (0.011)
GD	0.001*** (0.0001)				-0.000017 (0.0003)		
GD^2					0.000007*** (0.000002)		
SD		0.0001*** (0.000005)				0.00016*** (0.000008)	
SD^2						0.00000003*** (0.000000003)	
IPP			0.061*** (0.010)				
PDC				0.074*** (0.011)			0.169*** (0.038)
PDC^2							-0.085*** (0.029)
RES	0.0044*** (0.0001)	0.0042*** (0.0001)	0.0040*** (0.0001)	0.0042*** (0.0001)	0.0044*** (0.0001)	0.0043*** (0.0001)	0.0042*** (0.00008)
FDI	-0.0021*** (0.0006)	-0.0024*** (0.0006)	-0.0024*** (0.0007)	-0.0023*** (0.0006)	-0.0023*** (0.0006)	-0.0023*** (0.0005)	-0.0023*** (0.0006)
EDUE	-0.0016*** (0.0004)	-0.0015*** (0.0004)	-0.0032*** (0.0003)	-0.0033*** (0.0003)	-0.0021*** (0.0004)	-0.0012*** (0.0004)	-0.0032*** (0.0003)
TE	-0.0012***(0.0001)	-0.0015*** (0.0001)	-0.0013*** (0.0001)	-0.0012*** (0.0001)	-0.0013***(0.00009)	-0.0016*** (0.0001)	-0.0012*** (0.0001)
OFDI	0.0017*** (0.0005)	0.0020*** (0.0005)	0.0020*** (0.0005)	0.0019*** (0.0005)	0.0019*** (0.0005)	0.0018*** (0.0004)	0.0019*** (0.0005)
Country & year	yes	yes	yes	yes	yes	yes	yes
R2	0.8319	0.8470	0.8183	0.8195	0.8354	0.8509	0.8289
F	652.388***	729.9184***	593.651***	598.44***	572.6768***	644.1610***	546.737***
N	798	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

4.5 Heterogeneity analysis

4.5.1 Heterogeneity analysis of different country types

In order to examine the differences in the effect of overseas patent network layout on exports in different economies, this paper sets up a country dummy variable dc with reference to the World Bank's classification criteria for developed and developing countries, with dc=1 for developed countries and dc=0 for developing countries. In Table 8, columns (1) - (4) show the regression results of the quantity of exports on the layout of overseas patent network, and columns (5) - (8) show the regression results of the regression results of export quality on overseas patent network layout. As can be seen from the table, the export effects of the breadth and depth of overseas patent networks and the share of overseas invention patent applications vary significantly across economies. Column (1) and (3) show that the overseas patent network breadth, quality variables and their interaction terms with country dummy variables can pass the 1% significance level test and the direction of the coefficients is positive, which indicates that the level of national economic development plays a positive role in the impact of the breadth of overseas patent networks and the share of overseas invention patent applications on the number of exports, i.e., for developed countries, the positive impact of the breadth of overseas patent networks and the share of overseas invention patent applications on the number of exports is more pronounced, possibly because developed countries' overseas patent networks are more mature, and their marginal costs of expanding their overseas patent networks are smaller and more beneficial. From Column (2) and Column (4), the coefficients of the depth of overseas patent network and the share of layout in developed countries are positive, and the coefficients of the interaction terms are both negative, which both pass the test of significance level of 1%, which suggests that the effect of the depth of overseas patent network on the number of exports is greater in developing countries than in developed countries, i.e. for developing countries, the depth of overseas patent network and the proportion of layout in developed countries have a stronger effect on the number of exports, probably because the construction of overseas patent network of most developing countries is still in the primary stage, and the export effect of the depth of patent network is still in the stage of marginal increment, while on the contrary, the developed countries have experienced a marginal decreasing or even a negative effect in some markets. Similarly, as shown in Columns (5)-(8), the positive impacts of the breadth and depth of overseas patent networks and the proportion of layouts in developed countries on the quality of exports of developing countries are significantly higher than those on developed

countries, while the impacts of the proportion of overseas invention patent applications on the quality of exports of the two types of economies are not significantly different. To sum up, compared with developing countries, the breadth of overseas patent networks and the proportion of overseas invention patent applications in developed countries have a greater impact on the quantity of exports; compared with developed countries, the depth of overseas patent networks and the proportion of layouts in developed countries in developing countries have a stronger contribution to the quantity and quality of exports, and the breadth of overseas patent networks has a stronger effect on the quality of exports. This also confirms the paths and trends of overseas patent network layout in different economies: developed countries are more inclined to expand overseas patent markets and upgrade their patent technology level in order to expand the scale of exports, while developing countries are comprehensively strengthening their overseas patent layout in order to improve the comprehensive competitiveness of their exports.

Table 8 Analysis of Variability Across Country Typologies

Variable	Export Quantity				Export quality			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cons	6.7905 (6.9024)	43.592***	61.898***	72.969*** (15.815)	13345.90***	18417.33***	18273.020***	16218.91***
DC	-80.158*** (13.065)	30.798** (3.121)	-33.230**	259.221***	4046.780***	4366.979***	4924.455*** (583.757)	16894.78***
GD	2.123 *** (0.141)				115.337*** (9.832)			
SD		1.530*** (0.167)				21.221*** (6.599)		
IPP			53.355* (8.879)				1989.768*** (713.924)	
PDC				32.216*** (10.617)				4472.005***
*DC*GD*	2.0141*** (0.311)				-40.382*** (9.948)			
*DC*SD*		-1.237*** (0.162)				-19.624*** (6.437)		
*DC*IPP*			102.205**				-1292.688 (792.626)	
*DC*PDC*				-284.945*** (41.5154)				-17101.78*** (2208.99)
RES	0.8309 *** (0.0893)	0.5805** (0.0743)	0.2696*** (0.1326)	0.4971*** (0.1059)	57.2222*** (8.1152)	43.1450*** (8.9885)	37.3210 *** (8.7503)	50.1351*** (9.2139)
FDI	-0.641*** (0.2466)	-1.158*** (0.302)	-1.2183*** (0.3509)	-1.7532*** (0.4815)	11.8079 (7.4002)	-7.6082 (5.3148)	-8.9109* (5.1554)	-10.8603 (7.8348)
EDUE	-2.8130*** (0.5475)	-2.506*** (0.3217)	-3.8604*** (0.6457)	-4.2310*** (0.6264)	35.8305* (19.8732)	-75.6914*** (18.2012)	-119.346*** (20.3335)	-129.854*** (22.5219)
TE	2.3929***(0.2336)	2.0575*** (0.2560)	1.9710 (0.2272)	2.2297*** (0.2845)	118.8535*** (7.2448)	105.2595*** (6.3177)	107.7382*** (5.9106)	116.6155*** (7.6069)
OFDI	0.3721** (0.1657)	0.9720*** (0.159)	1.0032*** (0.1886)	1.3261*** (0.2672)	-10.9933 (7.5820)	8.9936** (4.5782)	9.4459** (4.5660)	0.9089* (6.4955)
Country & year	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.6353	0.5046	0.2443	0.2861	0.6621	0.3998	0.3757	0.4358
F	171.769***	100.45***	31.888***	39.521***	193.220***	65.708***	59.352***	76.191***
N	798	798	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

4.5.2 Analysis of the differential impact of different patent types

In order to test the differential impact of different types of overseas patent network layout on exports, we categorize overseas patents into three types: invention patents, utility model patents and design patents, and examine the impact of the breadth and depth of their network layouts on the quantity and quality of a country's exports respectively. Table 9 shows the regression results of the impact of different patent network breadth on export quantity and export quality, and Table 10 shows the regression results of the impact of different patent network depth on export quantity and quality.

In terms of overseas patent network breadth, as shown in Table 9, the coefficients of overseas invention patent network

breadth (IGD), utility model patent network breadth (UGD), and design patent network breadth (DGD) are all positive, and they all pass the significance level test of 1 percent, suggesting that all three types of overseas patent network breadth are positively correlated with the quantity and quality of exports. The results from the number of exports show that the estimated coefficient of the utility model patent network breadth variable is the largest, followed by invention patents and finally design patents. This indicates that overseas utility model patent network breadth has the greatest contribution to export quantity and overseas design patent network breadth has the least contribution to export quantity. The results for export quality show that overseas utility model patent network breadth has the largest positive impact on export quality, and design patent network breadth has the smallest positive impact on export quality, and that there is a large difference in the marginal increment in export quality between the two. The possible reasons for this are that utility model patents are more applicable and economical in overseas markets, and are more conducive to promoting productivity and innovation levels, thus improving export quantity and quality; design patents are mainly used to solve problems such as patent litigations and disputes in overseas markets, and provide legal and regulatory protection for home market entities to enter the host country's market, and thus are more conducive to the growth of export scale, and have less impact on export. The layout of invention patents in different overseas markets can make full use of the resources of different host country markets, reduce marginal costs, expand the scale of exports, and obtain a favorable competitive position through technological advantages, thus improving the quality of exports.

Table 9 Differential Analysis of the Breadth of Different Patent Types

Variable	Export Quantity			Export quality		
	(1)	(2)	(3)	(4)	(5)	(6)
Cons	-41.142***	19.220***	1.446	17203.280***	19828.750***	19906.240***
	(6.855)	(5.603)	(5.557)	(470.347)	(422.047)	(450.355)
IGD	4.529***			130.233***		
	(0.232)			(5.042)		
UGD		11.130***			304.242***	
		(0.499)			(12.788)	
DGD			3.933***			88.885***
			(0.153)			(4.061)
RES	0.4987***	0.5909***	1.2101***	28.8751***	16.7406***	33.8453***
	(0.1059)	(0.0900)	(0.0874)	(5.9241)	(5.9903)	(6.4335)
FDI	-0.4894**	-0.4535***	-0.9204***	22.9052***	17.5704*	13.2543
	(0.2184)	(0.1261)	(0.2664)	(8.8350)	(9.3423)	(9.1708)
EDUE	-0.7941	-1.7211***	-2.4386***	-75.6093***	-106.267***	-147.0626***
	(0.5273)	(0.4847)	(0.4388)	(26.0762)	(27.8492)	(27.8757)
TE	1.5216***	1.8296***	2.0134***	126.8925***	126.0063***	126.8215***
	(0.1810)	(0.1823)	(0.1992)	(8.4398)	(9.5037)	(9.3054)
OFDI	0.2615**	0.3634***	0.7704***	-12.6601	-10.2132	-3.1514
	(0.1810)	(0.0960)	(0.2118)	(8.0133)	(8.6289)	(8.5766)
Country & year	yes	yes	yes	yes	yes	yes
R^2	0.5920	0.5846	0.5423	0.5813	0.5527	0.5145
F	191.318***	185.548***	156.206***	183.035***	162.897***	139.710***
N	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

In terms of overseas patent network depth, as shown in Table 10, the coefficients of overseas invention patent network depth (ISD), utility model patent network depth (USD) and design patent network depth (DSD) are all positive and pass the 1% significance level test, indicating that all three types of overseas patent network depth are positively related to export quantity and quality. The results in Columns (1)-(3) show that the design patent network depth has the greatest contribution to the quantity of exports, followed by utility model patents, and the invention patent network depth has the least contribution to the quantity of exports. Columns (4)-(6) show that the depth of network of utility model patents has the largest contribution to the quantity of exports, followed by design patents, and the depth of network of invention patents has the smallest contribution to the quality of exports. Analyzing the reasons, compared with utility model patents and appearance patents, invention patents have the highest degree of innovation, and multiple layouts of invention patents in the same overseas market make the resources too concentrated in the host market, causing technological embargoes in the host market, and weakening the motivation to innovate of the market main body, which is unfavorable to the enhancement of the quality of exports. In addition, excessive placement of patents on overseas inventions may create market monopolies, leading to increased intervention and regulation by the host government, thus inhibiting the growth of the number of exports from the home country. Appearance patents are the least innovative and are less subject to host government intervention due to greater depth of layout. A greater depth of patents on the exterior

means that the home country is better able to understand the market environment of the host country and to integrate and use local resources, which leads to lower transaction costs and stimulates export behavior and investment in technological innovation.

Table 10 Differential Analysis of the Depth of Different Patent Types

Variable	Export Quantity			Export quality		
	(1)	(2)	(3)	(4)	(5)	(6)
Cons	78.509***	84.751***	44.165***	24373.870***	24431.130***	23408.070***
	(8.000)	(8.773)	(5.316)	(788.948)	(766.584)	(824.889)
ISD	0.300***			1.940***		
	(0.012)			(0.236)		
USD		2.283***			27.693***	
		(0.723)			(4.460)	
DSD			2.878***			25.711***
			(0.1171)			(2.932)
RES	0.6876***	0.6244***	0.8206***	12.4662	12.9907	16.9818*
	(0.0663)	(0.0776)	(0.0734)	(9.7919)	(9.6522)	(9.9789)
FDI	-1.2372***	-1.3135***	-0.8843***	-8.3950	-8.6569	-3.4986
	(0.3217)	(0.3929)	(0.1729)	(5.7811)	(5.8052)	(5.9204)
EDUE	-3.3544***	-3.8622***	-2.4504***	-286.368***	-295.582***	-246.874***
	(0.3434)	(0.4389)	(0.3073)	(23.0220)	(24.5843)	(23.5494)
TE	2.2488***	2.6693***	1.9453***	124.9191***	126.7544***	123.1263***
	(0.2433)	(0.2550)	(0.1607)	(8.3706)	(7.6317)	(8.5441)
OFDI	1.0182***	0.9447***	0.8942***	18.5298***	17.9170***	14.8539***
	(0.1748)	(0.2404)	(0.1866)	(5.9469)	(6.0162)	(5.3439)
Country & year	yes	yes	yes	yes	yes	yes
R^2	0.4982	0.3017	0.5655	0.2616	0.2722	0.3025
F	130.892***	56.9535***	171.568***	46.709***	49.299***	57.179***
N	798	798	798	798	798	798

Note: *, ** and *** are significance levels of 10%, 5% and 1%, respectively, with standard errors in parentheses.

5 CONCLUSIONS AND RECOMMENDATIONS

Using overseas patent data from 60 countries from 2000 to 2018, this paper empirically examines the dual influence effect and mechanism of overseas patent network layout on a country's export quantity and export quality from the multi-dimensional aspects of overseas patent network breadth, depth and quality. It is found that: (1) The breadth and depth of overseas patent networks and the proportion of overseas invention patent applications have a significant positive impact on the quantity and quality of a country's exports, while the proportion of patent layouts in developed countries has a significant negative impact on the quantity of a country's exports, and a non-significant impact on the quality of exports. (2) The role of the breadth of overseas patent network on the quantity of a country's exports shows a 'U-shaped' relationship, and the role of the quality of a country's exports shows an 'inverted U-shaped' relationship. The depth of overseas patent network and the proportion of patent layout in developed countries show an 'inverted U-shaped' relationship for both the quantity and quality of a country's exports. (3) Analyses of the heterogeneity of patent applicant countries show that the export effect of overseas patent networks varies across economies. For developed countries, expanding overseas patent layout markets and upgrading the level of patented technology can lead to a larger scale of exports. For developing countries, increasing the depth of patent layout and patent layout in developed countries is more conducive to expanding the scale of exports, and improving the breadth and depth of overseas patent networks and patent layout in developed countries is more conducive to improving the quality of exports. (4) After considering the differences in patent types, it is found that the breadth of the utility model patent network and the depth of the design patent network have a stronger positive impact on the quantity and quality of exports, and the marginal utility brought about by the increase in the depth of the invention patent network is lower.

A country's overseas patent applications are not the more the better, and a reasonable overseas patent network layout and structure can bring higher export performance. The main policy implications of this paper are: (1) Encourage international patent applications and technology mergers and acquisitions, reasonably strengthen the diversification of the host country's market, form the networked and scaled advantages of overseas patent layout, and realize the superposition of the positive effects of the breadth of the patent layout on the quantity and quality of exports. (2) Strengthening cooperation with local institutions in host countries, guiding enterprises to operate continuously in the same host country market, improving the degree of embeddedness and quality level of overseas patent network, accumulating independent intellectual property rights continuously, and obtaining competitive advantages in export. (3)

Reasonably dispersing resources and carrying out overseas patent layout in countries with emerging economies such as 'the Belt and Road', so as to reduce costs and market competition pressure, and thus improve export performance. (4) Choose different patent layout paths and strategies according to the country's level of development and objectives, and pay attention to the differences in the impact of different types of patent layout, so as to obtain greater marginal gains and long-term enhancement of a country's international competitiveness.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

National Natural Science Foundation of China (72474055,71974039), Guangdong Natural Science Foundation of China (2024A1515012263), Guangdong Philosophy and Social Science Planning Project (GD23CYJ13), Key Laboratory of Humanities and Social Sciences in Guangdong General Colleges and Universities (2022WSYS005), Guangdong University of Foreign Studies Key Laboratory of Global Governance and Community of Human Fate Key Laboratory of Guangdong University of Foreign Studies and Guangdong Philosophy and Social Science Innovation Project 2024 Special Commissioned Project (GD24TWCXGC12,GD22TWCXGC12),Guangdong Province Science and Technology Plan Soft Science Project(2024A1010070010).

REFERENCES

[1] Li J Y, Li J, Chen R S. Research on the dual innovation effects of overseas patents: Process innovation or product innovation? World Economy Studies, 2018(03): 41-55+135.
[2] Qian X F, Xiong P. The dual margins of China's export growth and their determinants. Economic Research Journal, 2010, 45(01): 65-79.
[3] Jiang G H, Jiang D C. The "export effect" of Chinese enterprises' outward foreign direct investment. Economic Research Journal, 2014, 49(05): 160-173.
[4] Cabral M H C. Export diversification and technological improvement: recent trends in the Portuguese economy. GEE papers, 2008(0006).
[5] Zheng Z P, Yue S. Institutional quality, population structure, and export sophistication. Journal of Beijing Institute of Technology (Social Sciences Edition), 2020, 22(02): 70-78.
[6] Zhu S, Fu X. Drivers of export upgrading. World Development, 2013, 51: 221-233.
[7] Wang Y J, Sheng D, Shi B Z, et al. How does infrastructure improve export sophistication?. Economic Research Journal, 2010, 45(07): 103-115.
[8] Keller W. International trade, foreign direct investment, and technology spillovers[M]//Handbook of the Economics of Innovation. North-Holland, 2010, 2: 793-829.
[9] Moussa B, Varsakelis N C. International patenting: An application of network analysis. The Journal of Economic Asymmetries, 2017, 15: 48-55.
[10] Ma D, Yu Q, Li J, et al. Innovation diffusion enabler or barrier: An investigation of international patenting based on temporal exponential random graph models. Technology in Society, 2021, 64: 101456.
[11] Zhou D, Peng J, Gao X. Examining export trade and corporate innovation: A multiphase difference-in-differences method. China Journal of Accounting Research, 2021, 14(2): 207-230.
[12] Yu D X, Liu H Y. Research on the impact of China's independent innovation capability on export trade: An empirical study based on patent grants. Journal of International Trade, 2008(03): 28-33.
[13] Ozsoy S, Fazlioglu B, Esen S. Do FDI and Patents Drive Sophistication of Exports? A Panel Data Approach. 2021.
[14] Blind K, Jungmittag A. Trade and the impact of innovations and standards: The case of Germany and the UK. Applied economics, 2005, 37(12): 1385-1398.
[15] Chen W C. The extensive and intensive margins of exports: The role of innovation. The World Economy, 2013, 36(5): 607-635.
[16] Cai Z H, Wang Y F, Dong G W. Research on the relationship between China's patents and export structure in "Belt and Road" countries: An analysis based on industry-level similarity index. Journal of International Trade, 2016(07): 61-71.
[17] Willoughby K W. Endogenous innovation, outward-bound international patenting and national economic development. The Journal of Technology Transfer, 2020, 45(3): 844-869.
[18] Soete L L G. A general test of technological gap trade theory. Weltwirtschaftliches Archiv, 1981, 117(4): 638-660.
[19] Wang W R. Technical standards, trade barriers, and international economic effects: An empirical analysis based on countries along the "Belt and Road". Journal of International Trade, 2018(09): 80-94.
[20] Li Q, Zhong Z C. The impact of overseas patent layout on China's outward foreign direct investment: An empirical study based on country-level panel data from 2002-2014. Management Review, 2017, 29(05): 40-51.
[21] Lileeva A, Trefler D. Improved access to foreign markets raises plant-level productivity… for some plants. The Quarterly journal of economics, 2010, 125(3): 1051-1099.
[22] Zhou D, Huang J, Zhao Y. Employee stock ownership plans and corporate innovation. 2019, 3: 63-70.
[23] Antoniades A. Heterogeneous firms, quality, and trade. Journal of International Economics, 2015, 95(2): 263-273.

[24] Hallak J C, Sivadasan J. Product and process productivity: Implications for quality choice and conditional exporter premia. Journal of International Economics, 2013, 91(1): 53-67.
[25] Zhao W X, Yang J G. Trade diversification and technological innovation: Stabilizers of export fluctuations—Mechanisms of trade barriers weakening export fluctuations and China's experience. West Forum, 2021, 31(02): 27-39.
[26] Huang Y Z, Zhong C B, Ye J S, et al. Cross-border investment and innovation performance: An analysis based on the breadth and depth of outward investment. Economic Research Journal, 2021, 56(01): 138-154.
[27] Li G, Li J, Zheng Y, et al. Does property rights protection affect export quality? Evidence from a property law enactment. Journal of Economic Behavior & Organization, 2021, 183: 811-832.
[28] Lerner J. The importance of patent scope: an empirical analysis. The RAND Journal of Economics, 1994: 319-333.
[29] Clarke J E, Liesch P W. Wait-and-see strategy: Risk management in the internationalization process model. Journal of International Business Studies, 2017, 48(8): 923-940.
[30] Liesch P W, Welch L S, Buckley P J. Risk and uncertainty in internationalization and international entrepreneurship studies//The multinational enterprise and the emergence of the global factory. Palgrave Macmillan, London, 2014: 52-77.
[31] Bai T, Liesch P. Organizational goals and RES allocation to overseas foreign direct investment. Journal of World Business, 2022, 57(3): 101308.
[32] Kiendrebeogo Y. Learning by exporting or self-selection into exporting?. Middle East Development Journal, 2020, 12(2): 304-325.
[33] Helpman E, Melitz M J, Yeaple S R. Export versus FDI with heterogeneous firms. American economic review, 2004, 94(1): 300-316.
[34] Liu X, Zhang T S, Qu R X. Foreign patents in China and Chinese enterprises' export behavior: Theoretical and empirical analysis from intra-industry and inter-industry perspectives. Economic Review, 2021(05): 118-135.
[35] Han X F, Hui N, Song W F. Has trade liberalization affected R&D innovation efficiency? Journal of Finance and Economics, 2015 (2): 15-26.
[36] Palangkaraya A, Jensen P H, Webster E. The effect of patents on trade. Journal of International Economics, 2017, 105: 1-9.
[37] Xu Y. Challenges and countermeasures of China's exports encountering patent barriers. International Trade, 2014 (5): 30-35.
[38] Lall S, Weiss J, Zhang J. The "sophistication" of exports: A new trade measure. World development, 2006, 34(2): 222-237.
[39] Rodrik D. What's so special about China's exports?. China & World Economy, 2006, 14(5): 1-19.
[40] Zheng Y Y, Guo R Q, Li L. Trade and the quality of innovation in Chinese enterprises: Evidence from the quality of enterprise patents. International Business (Journal of University of International Business and Economics), 2021(06): 1-17.
[41] Li H, Wang Y T, Wu D S. The impact mechanism of patent quality on enterprise export competitiveness: An exploration based on the perspective of knowledge breadth. World Economy Studies, 2021, (01): 32-46+134.
[42] Yang Z, Liu G C, Liu F. Financial development and dual economic structure imbalance: A new perspective based on factor allocation. Management Review, 2020, 32(11): 48.
[43] Lv Y, Chen S, Sheng B. Does embedding in global value chains lead to "low-end locking" of Chinese manufacturing? Management World, 2018, 8: 11-29.
[44] Koopman R, Powers W, Wang Z, et al. Give credit where credit is due: Tracing value added in global production chains. National Bureau of Economic Research, 2010.