

Does Patent Portfolio Drive Global Value Chain Climbing?—Empirical Evidence From China

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ABSTRACT Under the new era of China's high-quality development, the innovation driving of enterprises is shifting from single patent competition to patent portfolio competition, which is of great significance for cultivating a more robust domestic market and realizing a higher level of opening-up. This paper puts the firms' patent portfolio index and domestic value-added ratio into a unified analysis framework. It explores the relationship between them by utilizing the Chinese Industrial Database, Chinese Financial Database and China Customs Database from 2000 to 2014. The empirical results suggest that: (1) Domestic patent portfolio plays a significant role in promoting enterprises' export domestic value-added ratio, the suitability of domestic invention and utility model patents is not high in China; (2) Based on the heterogeneity analysis, the domestic patent portfolio of public trading enterprises and high productivity enterprises has a more significant promotion effect on domestic value-added ratio. (3) By examining the mechanism, it shows that price-cost markup and the relative price of intermediate goods are significant intermediate variables of domestic patent portfolio promoting domestic value-added ratio, and patenting abroad is an essential channel of domestic invention patent promoting domestic value-added ratio. This paper made an in-depth analysis of the influence of domestic patent portfolio on domestic value-added ratio, which provides a policy reference value for optimizing the Chinese patent system and enhancing competitive export advantage.

INDEX TERMS Patent portfolio, domestic value-added ratio, price-cost markup, foreign patent.

I. INTRODUCTION

In the process of China's promotion of the global economic cycle, the deepening of the international specialization enables China to participate in the manufacturing of high-tech products at a lower threshold. However, it remains at the lower part of the smiling curve. The disadvantages of China's lack of ability to create innovative products are gradually emerging [1]. China cannot transform from a large trading nation to a strong one without the sustainable innovation of export enterprises [2]. Patent, an important aspect to measure the innovation activities of enterprises, is the most valuable intangible asset to enhancing the added value of products [3]. Nowadays, the patent world is undergoing a transformation from tactical competition characterized by a single patent to strategic competition characterized by a patent portfolio. A high-quality patent portfolio enhances Chinese enterprises

to form a solid domestic market and realize the competitive edge of higher levels of trade.

Intermediate goods trade becomes an important form of international trade driven by the global value chain division system. Kee and Tang [4] and Lv Yue *et al.* [5] utilized the Chinese Industrial Database and China Customs Database to construct the measurement method of enterprises' export domestic value-added ratios (DVAR) at the micro-level. It can reflect the international trade profits of enterprises under the global value chain division system. With the maturity of the firm heterogeneity theory, the exploration of enterprises' DVAR from the micro perspective has been enriched. Scholars analyzed the influencing factors of enterprises' DVAR from the perspectives of FDI [6], financing restriction [7], trade facilitation [8], upstream monopoly [9], RMB devaluation [10], digitization [11], government subsidy [12], technology gap [13], and industrial agglomeration [14].

In moving to the forefront of global technology, China, as an emerging economy, is undergoing a transition from making mature products to invention products [15]. Local

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innovation is an essential intermediary for China's manufacturing industry to move towards the high-end of the global value chain [16]. As a carrier of patent technology, standardized indicators observable in patent documents play a vital role in economic and trade growth [17]. As a secondary patent protection system, utility model patents are considered an adequate institutional arrangement for developing countries to achieve innovation catch-up [18]. On the whole, enterprises can improve their productivity through technological innovation to improve the price-cost markup, reduce the relative price of intermediate goods, and ultimately promote the DVAR [19]. Meanwhile, With the improvement of domestic patent quality, emerging countries begin to carry out "reverse innovation" [20], and the endogenous demand for enterprises to apply for foreign patents is gradually significant [21]. Foreign patents can provide a standard legal guarantee for exporting products in the destination country, then opening the channel for increasing the added value of products [22]. The existing literature mainly researches enterprise patent level from patent number, patent type, and other quantitative indicators. From a systematic perspective, Wagner proposed that the value of an enterprise patent portfolio will be much greater than the value of a single patent [23]. Only comprehensive innovation or re-creation based on multiple technologies can capture the market [24]. Therefore, based on the domestic patent portfolio analysis perspective, this paper discusses enterprises whether through domestic patent portfolio to get rid of the dependence on the global value chain, to strengthen domestic market advantage, and improve the enterprises' DVAR. The conclusions provide necessary enlightenment for cultivating competitive advantage under the new stage of development in China, enhancing the toughness of the opening to the outside world and initiative.

Compared with the existing literature, the main contributions of this paper are listed as follows: (1) based on the theory of Kee and Tang [4], this paper puts the firms' domestic patent portfolio index and the DVAR into a unified analysis framework. It investigates the influence mechanism of the domestic patent portfolio on enterprises' DVAR, which provides new theoretical support for promoting the status of Chinese enterprises in the global value chain. (2) structural domestic patent portfolio indicators are constructed to measure the depth and width of the domestic patent portfolio. And the micro impact of enterprise patent portfolio on enterprises' DVAR is investigated. (3) This paper empirically tests the mediating role of price-cost markup, the relative price of intermediate goods and patenting abroad in promoting the improvement of enterprises' DVAR, and further expands the improvement path of enterprises' DVAR. (4) At present, most literature is based on the Chinese Industrial Database from 2000 to 2008. However, this paper adopts scientific accounting methods to complete the database of Chinese industrial enterprises from 2009 to 2014. The patent data from 2001 to 2020 and the Chinese Financial Database and China Customs Database from 2000 to 2014 are employed to provide more

time-sensitive data support for studying enterprises' innovation and the DVAR.

II. THEORETICAL FRAMEWORK AND HYPOTHESIS

Referring to Kee and Tang[4], the enterprises' export DVAR is expressed as:

$$DVAR_{it} = 1 - \alpha_m \frac{1}{1 + (p_t^F/p_t^D)^{\eta-1}} \frac{1}{markups_{it}} \quad (1)$$

where $DVAR_{it}$ denotes the export DVAR of company t in year i . α_m represents the output elasticity of intermediate factors. η is the elasticity of substitution between domestic intermediate goods and foreign intermediate goods. p_t^F and p_t^D are the price of foreign intermediate goods and domestic intermediate goods, respectively. $markups$ express the price-cost markup ratio.

The derivative of the relative price of intermediate goods and price-cost markup ratio obtains:

$$\frac{\partial DVAR_{it}}{\partial (p_t^F/p_t^D)} = \alpha_m \frac{1}{1 + (p_t^F/p_t^D)^{\eta-1}} \frac{1}{markups_{it}^2} > 0 \quad (2)$$

$$\begin{aligned} \frac{\partial DVAR_{it}}{\partial (p_t^F/p_t^D)} &= \alpha_m \frac{1}{markups_{it}} \frac{1}{\left[1 + (p_t^F/p_t^D)^{\eta-1}\right]^2} \\ &\times (\eta - 1) (p_t^F/p_t^D)^{\eta-2} > 0 \quad (3) \end{aligned}$$

According to Equations (2) and (3), increasing the relative price of intermediate goods and markup ratio can promote the DVAR. In what follows, how an enterprise's domestic patent portfolio ultimately affects the enterprises' DVAR by influencing the relative price of intermediate goods and markup ratio is discussed.

First of all, an enterprise's ability of independent innovation is the key to obtaining the ability to "cross the threshold" [25]. As the "super patent" to improve the effectiveness of a single patent and realize the complementary advantages of multiple patents, the enterprises' domestic patent portfolio is conducive to helping clarify the direction of research and development, improve the efficiency of research and development, reduce the risks caused by innovation uncertainty [26], and enable enterprises to obtain scientific and systematic innovation advantages. It realizes the conversion of domestic intermediate goods to foreign intermediate products by narrowing the technological gap [27]. Secondly, Patent provides knowledge producers with the temporary exclusive right to use the benefits of new technology and is also a powerful weapon for enterprises to improve market competitiveness [3], [28]. Through the distribution of core technology patents, enterprises form market power so that their marginal revenue exceeds their marginal cost and obtain more economic rents, which improve their price-cost markup [29]. In addition, an enterprise's patent portfolio is an effective means to check and balance its competitors. It can not only improve the entry threshold of the industry with domestic patent portfolio but also play games with competitors by patent cross-licensing and patent entry standards to further

maintain its competitive advantage [30]. To sum up, the domestic patent portfolio of the enterprise gradually breaks the competitive advantage of foreign intermediate suppliers in terms of technology and market, influences the price-cost markup and the relative price of intermediate goods, which plays a positive role in promoting the improvement of the enterprises' DVAR.

Hence, the following hypotheses are proposed in this paper:

Hypothesis 1: The enterprises' domestic patent portfolio is conducive to improving the DVAR.

Hypothesis 2: The domestic enterprises' domestic patent portfolio can improve the DVAR through "price-cost markup" and "relative price".

The basic patent is the core part of patent family [31], and the depth and width of an enterprise's domestic patent portfolio play a fundamental role in its practical foreign patent layout [32]. Patenting abroad as an essential business strategy and tool for multinational enterprises in global competition [33], can improve price-cost markup by Market coverage effect and competitive threat effect [34]. Meanwhile, foreign patent licenses and royalties can be obtained and enhance the DVAR by reducing financing constraints. However, the process of patenting abroad of enterprises is complicated, time-consuming and highly professional. Export enterprises that conduct foreign patent layouts have to pay high patent application operating expenses [35], which may inhibit enterprises' DVAR. Because most common law countries do not have utility model system, this section proposes the following hypotheses based on invention patents:

Hypothesis 3: Domestic invention patent influences the DVAR by influencing the foreign patent. If the quality of domestic invention patents is higher, the effectiveness of foreign patents will be increased and the DVAR will be eventually promoted.

III. MEASUREMENT MODEL, VARIABLES AND DATA

A. SETTING OF MEASUREMENT MODEL

Because of the high fixed costs of enterprises' domestic patent portfolios, the sample may have strong selective bias [19]. According to the research achievements of existing literature, this paper adopts the Heckman model as the basic measurement model, explores the impact of the depth and width of enterprises' domestic patent portfolio on export DVAR, and set as follows:

$$DVAR_{it} = \alpha_0 + \alpha_1 dep_{it-type} + \alpha_2 X + \alpha_3 imr_{it-type} + \alpha_j + \alpha_t + \alpha_p + \varepsilon_{it} \quad (4)$$

$$DVAR_{it} = \alpha_0 + \alpha_1 wid_{it-type} + \alpha_2 X + \alpha_3 imr_{it-type} + \alpha_j + \alpha_t + \alpha_p + \varepsilon_{it} \quad (5)$$

where $DVAR_{it}$ denotes the domestic value-added ratio of export of company t in year i. $dep_{it-type}$ is the depth of a specific type of domestic patent portfolio of company t in year i. $wid_{it-type}$ represents the width of a specific type of domestic patent portfolio of company t in year i. type

indicates the type of patent, it includes the sum of invention patent and utility model patent p, invention patent i and utility model patent u, namely, $typep, u, i$. X is the control variable. $imr_{it-type}$ is the Inverse Mills ratio of company t in year i. α_0 is a constant term, and fixed effect of year α_t , industry α_j and region α_p is further added. ε_{it} is a random error term to reduce potential endogeneity problems.

B. VARIABLE MEASUREMENT

1) DOMESTIC PATENT PORTFOLIO

This paper uses domestic patent portfolio width and depth to represent the enterprises' domestic patent portfolio. Domestic patent portfolio width can denote the degree of technological diversification of an enterprise, and domestic patent portfolio depth is related to the complexity of technology itself [36], which is conducive to overcoming errors caused by "innovation bubble".

International Patent Classification (IPC) is a patent document classification standard that sets all patent-related technical fields according to the grade of "division - category - subcategory - large group - group" based on the Strasbourg Agreement on International Patent Classification. Patent often involves multiple technical fields and has multiple IPC classification numbers, among which the IPC main classification number refers to the classification number that can represent the invention information. Based on the technology branch items (i.e., the quantity information of IPC main classification number) and the number of patents involved in the enterprises' domestic patent portfolio, and referring to the domestic patent portfolio analysis tool of China National Intellectual Property Administration (CNIPA) [37], the depth and width of the enterprise domestic patent portfolio are defined as:

$$wid_{it-type} = ipc_{it-type} / IPC \quad (6)$$

wid is the width of the domestic patent portfolio. $ipc_{it-type}$ expresses the number of IPC main classification number and category of a specific type of patent accumulative involved by enterprise t till year i. IPC is the number of IPC main classification number and category of all technical fields. The larger $wid_{it-type}$ index value is, the more technical fields the enterprise patent layout covers, and the stronger the control ability of peripheral patents will be.

The depth of domestic patent portfolio is expressed as:

$$dep_{it-type} = patent_{it-type} / ipc_{it-type} \quad (7)$$

dep is the depth of the domestic patent portfolio. $patent_{it-type}$ is the cumulative number of patents of a specific type authorized by enterprise t by year i. $dep_{it-type}$ is the average number of patent under all IPC main classification numbers involved by the enterprise, i.e., the average number of authorized patents owned under major technical branches. The larger this index is, the more intensive the domestic patent portfolio of the enterprise will be. The deeper the enterprise develops, the more complex technology becomes.

2) CALCULATION OF ENTERPRISES' EXPORT VALUE-ADDED RATIO

Based on the studies of Zhang *et al.* [6] and Kee and Tang [4], this paper measures the ratio of domestic added value of enterprises' exports from a micro perspective, considering the use of imported products, intermediary trade and indirect import of domestic intermediate products. Firstly, referring to the study of Upward *et al.* [38], HS commodity codes were transformed into Broad Economic Categories (BEC) commodity codes, and capital goods and consumer goods imported from abroad were excluded. Only intermediate goods in imported goods were used as intermediate inputs in general trade. Secondly, since some Chinese enterprises may obtain intermediate import inputs indirectly through intermediate traders, this paper learns from Ahn *et al.* [39] to identify enterprises whose enterprise names include "import and export", "economy and trade", "trade", "science and trade" or "foreign economy and trade" as intermediate traders. Then calculates the percentage M_k of intermediate traders' import amount in total import under HS6 digit commodity code k, and assumes that the share of all enterprises indirectly importing such goods through intermediate traders is equal to M_k . In addition, as domestic raw materials used by enterprises contain imported ingredients, this paper sets the overseas ingredients of domestic intermediate input as 5-10% by referring to the study of Koopman *et al.* [40]. Therefore, the ratio of domestic added value exported by enterprises can be expressed as:

$$DVAR_{it} = \begin{cases} 1 - \frac{I_{itA}^p + \delta_{it}^p}{E_{it}^p} & \text{Processing trade} \\ 1 - \frac{E_{it}^o \left[\frac{I_{itA}^o}{D_{it}^o + E_{it}^o} \right] + \delta_{it}^o}{E_{it}^o} & \text{General trade} \\ \omega_{it}^p \left(1 - \frac{I_{itA}^p + \delta_{it}^p}{E_{it}^p} \right) + \omega_{it}^o \left(1 - \frac{E_{it}^o \left[\frac{I_{itA}^o}{D_{it}^o + E_{it}^o} \right] + \delta_{it}^o}{E_{it}^o} \right) & \text{Hybrid trade} \end{cases} \quad (8)$$

where DVAR is the ratio of domestic added value exported by an enterprise. *i* and *t* are the enterprise and year, respectively. Superscript p and o are processing trade and general trade. ω_{it}^p and ω_{it}^o are the proportion of the two trade modes. I, E and D represent enterprises' import, export, and domestic sales, respectively. The subtext bec denotes the intermediate goods under the BEC classification standard. I_{itA}^p is the actual

import amount of processing trade. I_{itA}^o is the actual import amount of intermediate goods in general trade. Considering that enterprises purchase overseas intermediate inputs from intermediate traders, this paper further represents the import amount of processing trade and the import amount of intermediate products of general trade as $I_{itA}^p = \sum_k \frac{I_{itk}^p}{1 - m_{itk}}$ and

$I_{itA}^o = \sum_j \frac{I_{it/hec}^o}{1 - m_{ij}}$. k and j represent the categories of products imported by enterprises through processing trade and the types of intermediate products imported by enterprises through general trade. E_{it}^o and E_{it}^p are the export volume of processing trade and general trade. δ is the volume of overseas imports in domestic intermediate input.

3) CONTROL VARIABLES

Firm age is identically equivalent to the number of years in the current year minus the year of establishment plus 1. Firm size refers to the ex-factory price index of industrial products based on 1998 is used to deflate the sales of enterprises, and then take the logarithm. Liability is the ratio of total assets to total liabilities. The profit is the ratio of operating profit to sales. Capital intensity refers to that the fixed assets are deflated based on the fixed assets investment price index in 1998, and then divided by the number of employees and taken as a logarithm. Internal-financing restriction is expressed as the ratio of the difference between current assets minus current liabilities and total fixed assets. Financing restrictions are measured by the ratio of interest payments to fixed assets. Export intensity is expressed as the ratio of export delivery value to enterprise sales.

C. DATA SOURCES AND DATA PROCESSING

Three types of data are considered in the quantitative analysis of this paper. The first type is the enterprise-level patent data, which is utilized to calculate the domestic patent portfolio variables; The second type is the financial data of an enterprise, which is used to calculate enterprise-level control variables such as firm size, firm age, and financing constraints. The third category is enterprise trade data, mainly employed to measure enterprises' DVAR.

The patent data were obtained from incoPat patent database. In this paper, the enterprise names in the China Industrial Enterprise database were accurately matched and fuzzy matched with the patentee of the patent database. 373258 domestic authorized patent documents of 10597 export enterprises and 25334 foreign patent documents applied internationally through PCT and Paris Convention were manually downloaded and sorted. The main fields included the number of inventions authorized by CNIPA, the number of IPC main classification numbers and the number of patent family, number of utility models authorized by CNIPA, number of IPC main classification number and number of the patent family. The number of IPC categories of enterprises can be derived by retrieving the IPC classification number of patent documents, extracting the

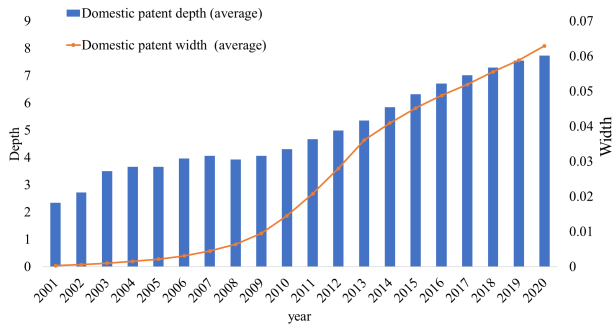


FIGURE 1. Evolution trend of domestic patent portfolios from 2001 to 2020.

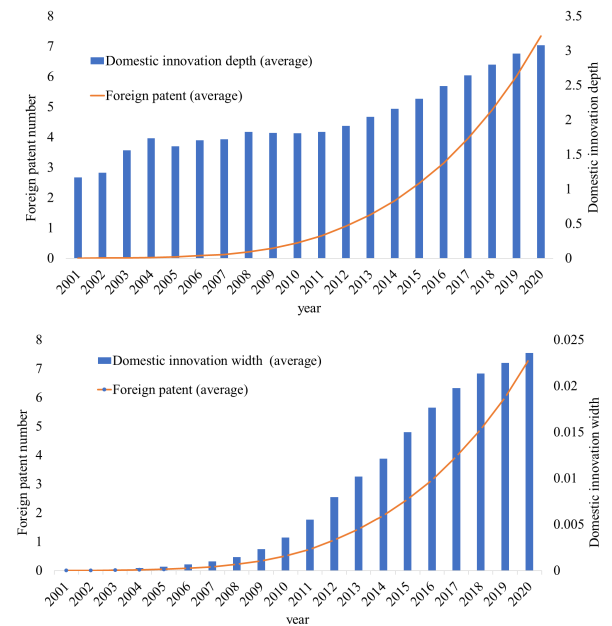


FIGURE 2. Evolution trend of domestic invention patent portfolio and foreign patents from 2001 to 2020.

main classification number of each patent, and deleting the repeated IPC classification number.

The financial data are from the Chinese Industrial Database from 2000 to 2014. When calculating the index of value-added ratio of enterprises' export, the date lacks industrial added value and industrial intermediate input data from 2008 to 2014. In this paper, referring to the data method of Yu Miao-jie [41], the industrial intermediate input is expressed as output value.

*cost of sales/sales/ – payment – salary depreciation in current year on in current year and then the industrial added value is presented as gross industrial out put value + value added tax-industrial intermediate input. Meanwhile, based on the existing literature, the samples of lacking enterprise sales, operating profit, fixed assets, current assets, current liabilities, total fixed assets, interest expenses, export delivery value, total liabilities and total assets were excluded, and the sample with negative number was excluded too.

The trade data of enterprises are from China Customs Database, and the data of Chinese Industrial Enterprises are

matched with the data of the China Customs Database year by year with according to Tian Wei and Yu Miao-jie [42].

D. FACTS ANALYSIS OF THE DOMESTIC PATENT PORTFOLIO OF EXPORT ENTERPRISES

Some scholars have tried to summarize typical facts about patent quality and quantity in China [43], But there are few typical facts about the domestic patent portfolio in China at present. This paper preliminarily describes and summarizes basic facts such as annual trend, industry heterogeneity and foreign patent growth of domestic patent portfolio based on patent data of export enterprises.

Typical fact 1: The annual change of Chinese export enterprises' domestic patent portfolio presents a "preliminary development-rapid upgrade-steady growth" trend.

Fig. 1 displays the evolution trend of the overall domestic patent portfolio in China from 2001 to 2020 based on sample data. From the perspective of the annual change trend, Chinese export enterprises' domestic patent portfolio index showed an upward trend from 2001 to 2020. Specifically, the domestic patent portfolio trend generally includes three development stages. 2000-2008 was a slow development stage, and both the width and depth of the domestic patent portfolio rose slowly. 2008-2014 was a rapid growth stage. Since China promulgated the outline of intellectual property strategy in 2008, the depth and width of enterprises' domestic patent portfolios have increased exponentially. After 2014, as China's economy shifted from high-speed development to high-quality development, the growth rate of the domestic patent portfolio of enterprises also slowed down.

Typical fact 2: The number of foreign patents of enterprises is consistent with the overall growth trend of the quality of domestic invention patent portfolio, and the number of foreign patents increases continually.

Patent competition is an essential means for technology enterprises to resist overseas risks. Fig. 2 depicts that the width and depth of the domestic invention patent portfolio from 2001 to 2020 is consistent with the overall trend of the number of foreign patent applications. The average depth of domestic invention patent portfolio from 2001 to 2020 increases from 1.167 to 2.975, with relatively slow growth. Domestic enterprises' average patent portfolio width increased from 0.00003 to 0.027, showing a trend of rapid growth at first and then gentle growth. After 2015, the growth rate of invention patent portfolio width gradually slowed down. The number of foreign patents increased from 0.00091 per enterprise to 5.776. After 2009, the number of foreign patents of enterprises showed an exponential growth trend.

IV. EMPIRICAL RESULTS AND ANALYSIS

A. BASELINE REGRESSION

Table 1 reports the baseline regression results between the enterprises' domestic patent portfolio and export DVAR in Heckman stage 2. Models (1) - (2) report the impact of

TABLE 1. The baseline regression results of the domestic patent portfolio on enterprises’ export DVAR.

	model(1) DVAR	model(2) DVAR	model (3) DVAR	model (4) DVAR	model (5) DVAR	model (6) DVAR
dep _{it-p}	0.001*** (3.721)					
wid _{it-p}		0.209*** (2.966)				
dep _{it-u}			0.003*** (4.217)			
dep _{it-i}				0.008*** (4.312)		
wid _{it-u}					0.189** (2.548)	
wid _{it-i}						0.490*** (3.336)
imr	0.101*** (6.080)	0.066*** (4.538)	0.067*** (3.450)	0.088*** (5.690)	0.067*** (4.681)	0.074*** (3.901)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
N	50553	50548	50542	50553	50548	50542
r2	0.030	0.029	0.029	0.030	0.029	0.029

Note: Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

TABLE 2. Regression results based on heterogeneity analysis.

	model (1)	model (2)	model (3)	model (4)	model (5)	model (6)	model (7)	model (8)
	Trade mode				Total-factor Productivity			
	Mach		Normal		High		Low	
dep _{it-p}	0.001 (0.894)		0.001*** (4.781)		0.001*** (3.596)		0.001 (1.621)	
wid _{it-p}		0.329 (1.503)		0.170*** (2.626)		0.227** (2.227)		0.167* (1.72)
imr	0.115* (1.817)	0.074*** (4.703)	0.089 (1.431)	0.065*** (4.415)	0.141*** (5.685)	0.124*** (5.369)	0.051* (1.876)	0.045* (1.783)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	6740	6740	43813	43813	24012	24012	26541	26541
r2	0.107	0.108	0.019	0.018	0.036	0.036	0.024	0.024

the depth and width of the domestic patent portfolio on the DVAR. The results show that the parameter estimation of the depth and width of the domestic patent portfolio is significantly positive. Farther, models (3) - (6) report the impact of the overall combination depth and width of utility model patents and invention patents on the DVAR, respectively. Regarding patent types, the estimated coefficient of an invention patent is greater than that of a utility model, and the estimated coefficient of a patent portfolio is smaller than that of invention patent depth and width. It indicates that invention patent is superior to utility model patent, the suitability of invention and utility model patents is not high in China.

B. HETEROGENEITY ANALYSIS BASED ON ENTERPRISE TRADE MODE AND TOTAL-FACTOR PRODUCTIVITY

1) REGRESSION ANALYSIS BASED ON THE TRADING MODE OF ENTERPRISES

Due to the different trade modes, the influence of enterprises’ domestic patent portfolio on DVAR may be distinct. In this paper, the sample enterprises are divided into processing trade enterprises (Mach) and general trade enterprises (Normal). As can be seen from Table 2, models (1) - (4) report the domestic patent portfolio of general trade enterprises has a significant effect on enterprises’ DVAR. In contrast, the domestic patent portfolio of

processing trade enterprises has no significant effect on enterprises' DVAR.

The possible reasons are provided as follows: Firstly, processing trade enterprises only undertake labor-intensive division of labor such as product assembly with low technical content, so domestic patent portfolio plays a weak role in improving the DVAR. Secondly, some processing trade enterprises are vulnerable in absorption and learning, the effect of "learning by doing" is inefficient, and the quality of the domestic patent portfolio is low, leading to the impact on the DVAR is not yet apparent. In addition, some processing trade enterprises with solid learning and absorption ability have successfully crossed the technological threshold from processing trade enterprises to general trade enterprises by absorbing technological spillover of imported intermediate goods and carrying out incremental innovation. Therefore, the promotion effect of the domestic patent portfolio on processing trade enterprises is not significant.

2) REGRESSION ANALYSIS BASED ON TOTAL-FACTOR PRODUCTIVITY

According to the median total-factor productivity, sample enterprises are divided into high and low productivity groups. From table 2, models (5) - (8) report domestic patent portfolio has a positive effect on enterprises' DVAR, the high productivity group of enterprises' domestic patent portfolio has a significant positive impact on enterprises' DVAR, and low productivity of the domestic patent portfolio has a positive influence not significant. The following reasons can explain it: high-productivity enterprises have vital research and development innovation ability, and pay more attention to cumulative innovation, and establish a higher quality domestic patent portfolio. Thus, the enterprises' domestic patent portfolio plays a more critical role in improving the DVAR of enterprises with high productivity.

C. ROBUSTNESS CHECKS

1) INDEX TRANSFORMATION

(a) Enterprises DVAR without considering indirect import. In the baseline regression, the calculation method of enterprises' DVAR mainly refers to Lv Yue [5]. Enterprises' DVAR is re-calculated without considering the indirect import of enterprises in this test. From table3, models (1) - (2) shows that enterprises' domestic patent portfolio still has a significant positive impact on the DVAR.

(b) Take the period of enterprises' domestic patent portfolio, which lagging by one stage as the explanatory variable. Since the domestic patent portfolio has a certain time lag in promoting enterprises' DVAR, this paper refers to lu Yue [44] to verify the robustness. It takes the domestic patent portfolio index lagging by one stage as the core explanatory variable for regression. From table3, models (3) - (4) describes that enterprises' domestic patent portfolio lagging by one stage significantly promotes the DVAR.

2) ENDOGENOUS TEST

The Heckman two-stage model can overcome the bias caused by self-selection of samples in the baseline regression. Still, there may be other endogenous problems such as omitted variables and bidirectional causality between enterprises' domestic patent portfolio and export DVAR. Based on the method of Lewbel [45], this paper uses the depth (width) of the domestic patent portfolio minus the third power of the average value of the depth (width) of the domestic patent portfolio as the instrumental variable of the domestic patent portfolio.

From table3, models (5) - (6) shows that the domestic patent portfolio significantly promotes the enterprises' DVAR. Meanwhile, Kleibergen-Paap rank test for under identification and also reject weak instruments hypothesis, indicating that the regression results are robust.

V. TEST OF MEDIATION MECHANISM

A. MODEL SETTING

To further explore the influence mechanism of the domestic patent portfolio on enterprises' DVAR, this paper introduces three mediators, including enterprise price-cost markup, the relative price of intermediate goods and foreign patenting, based on the baseline model. Referring to the method of Wen Zhonglin [46], this paper tests the intermediary effect and investigates the impact of the domestic patent portfolio on the DVAR. The mediation model is listed as follows:

$$\begin{aligned}
 DVAR_{it} &= \alpha_0 + \alpha_1 dep_{it} + \alpha_2 X + \alpha_3 imr_{it} + \alpha_j + \alpha_t + \alpha_p + \varepsilon_{it} \\
 M_{it} &= \beta_0 + \beta_1 dep_{it} + \beta_2 X + \beta_3 imr_{it} + \beta_j + \beta_t + \beta_p + \beta_{it} \\
 DVAR_{it} &= \alpha_0 + \alpha_1 dep_{it} + \alpha_2 X + \alpha_3 imr_{it} + \alpha_4 M_{it} + \alpha_j \\
 &\quad + \alpha_t + \alpha_p + \varepsilon_{it} \tag{9} \\
 DVAR_{it} &= \alpha_0 + \alpha_1 wid_{it} + \alpha_2 X + \alpha_3 imr_{it} + \alpha_j + \alpha_t + \alpha_p + \varepsilon_{it} \\
 M_{it} &= \beta_0 + \beta_1 wid_{it} + \beta_2 X + \beta_3 imr_{it} + \beta_j + \beta_t + \beta_p + \beta_{it} \\
 DVAR_{it} &= \alpha_0 + \alpha_1 wid_{it} + \alpha_2 X + \alpha_3 imr_{it} + \alpha_4 M_{it} + \alpha_j \\
 &\quad + \alpha_t + \alpha_p + \varepsilon_{it} \tag{10}
 \end{aligned}$$

The domestic patent portfolio can influence the enterprises' DVAR through three channels:

price-cost markup, the relative price of intermediate goods, and foreign patenting.

B. MEASURE OF INTERMEDIATE VARIABLE

1) Price-cost markup. This paper mainly refers to the production function method utilized by De Loecker and Warzynski [47] to measure the enterprise price-cost markup ratio (*markups*), and the equation is provided as follows:

$$\text{markups} = \rho(\vartheta)^{-1} \tag{11}$$

where ϑ is the proportion of intermediate input in enterprise sales. ρ expresses the output elasticity of intermediate input. To obtain the output elasticity of intermediate inputs, this paper sets the production function in the form of trans-logarithmic production function according to

TABLE 3. Robustness checks.

	model (1) DVAR	model (2) DVAR	model (3) DVAR	model (4) DVAR	model (5) DVAR	model (6) DVAR
dep _{it-p}	0.001*** (2.708)				0.001** (2.038)	
wid _{it-p}		0.180** (2.487)				0.581*** (5.935)
L.dep _{it-p}			0.001*** (3.149)			
L.wid _{it-p}				0.198** (2.512)		
imr	0.099*** (5.915)	0.087*** (5.652)	0.084*** (4.745)	0.072*** (4.320)		
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap rk LM					709.560 [0.00]	1057.441 [0.00]
Kleibergen-Paap Wald rk F					10744.95 [16.38]	6803.249 [16.38]
N	50553	50548	34153	34153	48166	48166
r2	0.030	0.030	0.024	0.024	0.028	0.027

DLW method, as follows:

$$\begin{aligned}
 lny = & \beta_l lnl + \beta_k lnk + \beta_m lnm + \beta_{ll} (lnl)^2 + \beta_{kk} (lnk)^2 \\
 & + \beta_{mm} (lnm)^2 + \beta_{lk} lnlnk + \beta_{lm} lnlnm + \beta_{km} lnklnm \\
 & + \beta_{lkm} lnlnklnm + tfp + \varepsilon \tag{12}
 \end{aligned}$$

where ε depicts the error term, $l k m$ represents labor capital and intermediate input, and tfp is enterprise total-factor productivity.

Using GMM method to estimate the above equation, and the following equation can be obtained:

$$\rho = \beta_m + 2\beta_{mm}lnm + \beta_{lm}lnl + \beta_{km}lnk + \beta_{lkm}lnlnm \tag{13}$$

Substitute the estimate of ρ and ϑ into Equation (11) to obtain the markup ratio.

2) Relative price of intermediate goods and foreign patenting. Due to the lack of data on the relative price of intermediate goods, this paper refers to the method of Gao Xiang (2018)[48] to take the proportion of domestic intermediate goods as a proxy variable of the relative price of intermediate goods (p_i^F / p_i^D). foreign patenting is represented by the number of patents in the same patent family other than those in CNIPA.

C. TEST OF MEDIATION MECHANISM

Models (1) and (3) in Table 4 show that enterprises' domestic patent portfolio coefficients are significantly positive, which indicates that the domestic patent portfolio significantly improves the enterprise price-cost markup. Models (2) and (4) show that both the domestic patent portfolio and the enterprise price-cost markup are quite optimistic after the mediating variable price-cost markup ratio added into the master regression, which indicates that the domestic patent portfolio has a significant indirect effect on enhancing the DVAR by increasing the price-cost markup

ratio of enterprises. Compared with the baseline regression, it can be found that the indirect effect of the domestic patent portfolio on the improvement of enterprises' DVAR through enterprise price-cost markup ratio is small, which indicates that home enterprises should give full play to the channel role of "domestic patent portfolio - price-cost markup - export DVAR" in the future, to enhance the markup ratio and the DVAR by improving the level of enterprise domestic patent portfolio.

Models (5) and (7) in Table 4 display that the domestic patent portfolio coefficients are significantly positive, and Models (6) and (8) show that the domestic patent portfolio and relative price coefficients are significantly positive, which indicate that the domestic patent portfolio has a significant indirect effect on enhancing the DVAR by increasing the relative price of intermediate goods. Therefore, enterprises improve the complexity of patent technology, enlarge the coverage of patent technology, which will help domestic enterprises crossing the technology innovation technology threshold, narrow the technology gap with foreign enterprises, reduce the use of imported products, to realize the transformation from imported intermediates to domestic products, and promote enterprises' DVAR.

According to the 2019 statistical annual report of China National Intellectual Property Administration, the number of foreign patents granted by Chinese inventors was 117,201, of which 91,885 were granted invention patents, accounting for 78.4% of the total. 8069 utility models were authorized, accounting for only 6.9% of the total number of foreign patents. The reason can be attributed to that most of the export destination countries of high-tech products are developed countries, while most of the countries applicable to the utility model system are developing countries. Thus, the invention patent has become the main force of patenting abroad of Chinese export enterprises. Table 5 examines whether the

TABLE 4. Mediation mechanism of price-cost markup and relative price.

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
	markups	DVAR	markups	DVAR	p_i^f/p_i^p	DVAR	p_i^f/p_i^p	DVAR
dep _{it-p}	0.001*** (5.034)	0.001*** (3.607)			0.001*** (4.191)	0.000* (1.898)		
wid _{it-p}			0.061* (1.774)	0.206*** (2.934)			0.159** (2.304)	0.144** (2.246)
markups		0.038*** (3.216)		0.039*** (3.301)				
p_i^f/p_i^p						0.410*** (31.565)		0.410*** (31.596)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	50553	50553	50553	50553	50553	50553	50553	50553
r2	0.422	0.030	0.421	0.030	0.059	0.155	0.059	0.155

TABLE 5. Test results of the mechanism among domestic invention patent, foreign-patent and export DVAR.

	Model (1) foreign-patent	Model (2) DVAR	Model (3) foreign-patent	Model (4) DVAR
dep _{it-i}	0.047*** (9.661)	0.007*** (4.048)		
wid _{it-i}			3.651*** (8.393)	0.447*** (3.033)
foreign-patent		0.011** (2.076)		0.012** (2.253)
Control variable	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	50542	50542	50542	50542
r2	0.064	0.029	0.064	0.029

domestic invention patent portfolio will promote the DVAR by patenting abroad. Models (1) and (3) show that the invention patent depth and width significantly increase the number of foreign patents. The influence coefficient of the invention patent width on the number of foreign patents reaches 3.651. As can be seen from models (2) and (4), both the domestic invention patent variable and the foreign patent variable are significantly positive. The depth and width of the domestic invention patent also have an indirect mediating effect on enterprises' DVAR through foreign patenting. Therefore, patenting abroad with a high-quality domestic invention patent helps improve enterprises' DVAR. And width of domestic invention patent to foreign patent plays a more significant role in it, causing the influence of the patent width to represent the enterprises' ability to control the surrounding patents. The stronger the control over surrounding patents, the more profound understanding of the market competition role of patents. By breaking the patent barriers of destination countries, reducing the export risks and improving the competitiveness of high-tech products, patenting abroad can promote enterprises' DVAR.

VI. CONCLUSION AND POLICY RECOMMENDATIONS

With the overall innovation capacity of Chinese enterprises has been enhanced, several high-tech enterprises with core

technologies have been developed in China, which promote China's position in the global value chain. Therefore, under the new era of high-quality development, it is crucial to upgrade the domestic path of GVCs by promoting the release of endogenous growth power of the Chinese economy through the domestic patent portfolio. In this paper, the enterprises' domestic patent portfolio and the DVAR of export are placed in the same analytical framework, and the relationship between the domestic patent portfolio and the export DVAR is deeply discussed by using enterprises' patent data from 2001 to 2020, Chinese Financial Database and China Customs Database from 2000 to 2014. The results show that: (1) The domestic patent portfolio positively affects the DVAR. (2) Based on heterogeneity analysis, it is observed that the domestic patent portfolio of general trading enterprises and high-productivity enterprises has a more significant promotion effect on DVAR in export. (3) Through the mediation mechanism test, it is found that the price-cost markup and the relative price of intermediate goods are essential mediators in improving the DVAR of the enterprises' domestic patent portfolio, and the foreign patenting is a vital way to promote the DVAR of the enterprises' domestic invention patent.

As an essential focus to promote the DVAR, the domestic patent portfolio of enterprises has important policy

implications for China's higher level of opening-up. Therefore, some suggestions were put forward as follows:

1) Guide enterprises to improve their awareness of the domestic patent portfolio play the complementary role of inventions and utility models patents. This paper found that the combination of domestic innovations and utility models promoting effect of export DVAR below domestic innovations in China, implies the synergistic impact of the domestic patent portfolio needs to be further improved. Therefore, the government should not only guide enterprises to layout invention patents but also guide enterprises to layout surrounding patents around the core technical, which can form a patent wall for the core technology through combining the invention patents and utility model patents so that fully play the market competition role of patents portfolio.

2) Enhance the guide precision of policy and implement more targeted differentiated the domestic patent portfolio guidance policies. At present, government policy takes a "one-size-fits-all" model from a macro level, which will lead to a poor effect, or even no impact in some areas, of these policies. Based on heterogeneity analysis, it is observed that the domestic patent portfolio of processing trading enterprises and low-productivity enterprises has no significant promotion effect on export DVAR. Therefore, the main point of the government's guide policy for low technology enterprises should be to encourage enterprises to carry out "improved" innovation and guide the enterprise to accumulate innovation. However, by including the quality of the domestic patent portfolio into the scope of scientific and technological achievements evaluation, the government guides high-productivity enterprises to pay more attention to the depth of technology research and development and the breadth of patent protection, which can improve the level of high-productivity enterprises' domestic patent portfolio gradually.

3) Optimize the quality of domestic invention patent and increase the distribution of foreign patents. An invention patent is a competitive tool for China to break through the "technology blockade" and reconstruct the global value chain. Enterprises should contribute to foreign patent high-quality layout by improving the quality of domestic invention patents in key fields. So that enterprises need to take the domestic patent portfolio as the focus to reduce the adverse impact of overseas patent barriers on export DVAR, and give full play to the promotion role of patenting abroad on enterprises' export DVAR.

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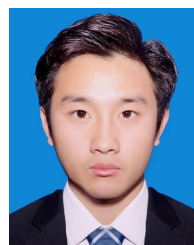


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