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Value-Added Trade, Trade Barriers, and International Technology Spillover—Evidence from China's Manufacturing Industry

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Abstract

Whereas the technology spillover effect of international trade has been widely concerned by academic circles, the impact of trade barriers on technology spillover has received relatively less attention. This paper assesses the heterogeneity of international technology spillover effects in China's manufacturing industry from traditional gross trade and value-added trade perspectives. Moreover, a deep insight into the effects of tariff and non-tariff barriers on international technology diffusion from traditional gross trade and value-added trade perspectives is also provided. Results show that the international trade indeed engenders technology diffusion, which is especially true in value-added trade characterized by intermediate goods trade compared with traditional gross trade. Additionally, tariff barriers severely disrupt technology diffusion in international trade, and traditional gross trade statistics underestimate the cumulative destructive effect of trade barriers on technology diffusion. Consequently, it can be concluded that reducing the abuse and misuse of non-tariff barriers can moderate the negative effect of trade barriers on international technology diffusion.

JEL classification numbers: F14.
Keywords: Global value chains; Value-added trade; Trade barriers; International technology spillover; Manufacturing industry.

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1. Introduction

The rapid development of the global production network and a new round of technological revolution and industrial transformation have spawned and promoted the establishment, development, integration, and reshape a new international division of labor system based on the global value chain (GVC) (Tsekeris, 2017). In particular, the proposal of the value-added trade accounting system based on the global value chain has had a subversive impact on traditional gross trade. The division of labor and development of the global value chain (GVC), mainly characterized by trade in intermediate goods, has facilitated the transfer and spillover of technological factors.

Technological spillover is a complex process that combines technological elements with economy, trade, FDI and market (Behera, 2017). Scholars have conducted lots of research on the causes, dynamics, scope and degree of technological spillover (Chang et al., 2013; Madsen and Farhadi, 2018; Chen et al., 2019; Sun et al., 2021). Existing studies have pointed out that product import and export trade is one of the main paths and methods of technology spillover (Coe and Helpman, 1995; Idris et al., 2021; Keller, 1998; Souare, 2013; Xu and Chiang, 2005; Yang et al., 2021). Earlier studies such as Grossman and Helpman (1991) have found that technology can be transferred and diffused through trade in intermediate goods. That is, when intermediate goods are exported, the productivity of the importing country will be improved through the R&D effect and technology transfer of its trading partners. Based on the theoretical framework of Grossman and Helpman's research, some researchers have quantitatively expanded and analyzed the technological spillover effect of international trade from the perspective of the stock of foreign R&D, import of intermediate and capital goods, and foreign direct investment based on the perspective of traditional gross trade (Becker and Peters, 1998; Cincera, 2005; Coe et al., 2009; Fracasso and Marzetti, 2015; Kao et al., 1996; Lumenga-Neso, 2005; Savvides and Zachariadis, 2005).

However, the traditional gross trade statistics used in the above research have serious deficiencies, which cannot truly reflect one country’s actual situation and benefits in international trade (Hummels et al., 2001; Koopman et al., 2010; Wang et al., 2013).

Value-added trade accounting system based on the theory of global value chain can statistic and analyze the source and destination of each category of added value, and re-allocate the surplus and deficit among countries (Johnson and Noguena, 2012; Koopman et al., 2014). It can also objectively indicate the real benefits and friction degree in bilateral and multilateral trade, and has become widely employed by lots of research (Wang et al., 2015; Wang et al., 2017). On the other hand, few research reveals the internal impact of trade friction caused by trade barriers on the effect of international technology spillover. Therefore, by taking China’s manufacturing industry as an example, this paper studies the effect of trade barriers on technological spillover from the perspective of value-added trade.

To achieve these goals, this study takes China’s tariff trade barrier and non-tariff barriers such as anti-dumping as a benchmark research scenario, and re-examines the effect of trade on international technology spillover from the perspectives of both traditional gross trade and value-added trade. Firstly, based on the CH model proposed by Coe and Helpman (1995) and the improved LP model proposed by Lichtenberg and Potterie (1998), this paper assesses the heterogeneity of international technology spillover effects in China's manufacturing industry from traditional gross trade and value-added trade perspectives. Secondly, we investigate the impact of tariffs and non-tariffs represented by anti-dumping trade barriers on the international technology spillover in China's manufacturing industry by using value-added trade data and traditional gross trade data.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature on the technology spillover effect of international trade, as well as the effect of trade barriers during the process of international trade technology spillover. The subsequent two describe the methodology, data and variables. Section 5 discusses the empirical results. The final section summarizes the findings and discusses policy implications.

2. Literature Review

Global economic integration increasingly promotes countries, industries and enterprises to expand internationalized innovation activities through international technical factors spillover (Yang et al., 2021). As an important way of technology spillover, international trade and its role in promoting technological progress have received a lot of attention from both academia and industry (Bitzer and Geishecker, 2006; Coe et al., 1997; Coe and Helpman, 1995; Eaton and Kortum, 1996; Funk, 2001; Grossman and Heplman, 1991; Keller, 1999). Coe and Helpman (1995) constructed the classic CH model to examine the dependence of a country's total factor productivity on domestic and foreign R&D capital on the basis of Grossman and Helpman model (Grossman and Helpman, 1991). The CH model validates the technology spillover effect of international trade and has thus become a widely used model in this field of technology spillover. Later, Engelbrecht (1997) assessed the robustness of the CH model with the inclusion of human capital variables. Coe et al. (1997) found that developing countries can capture larger R&D spillover from developed countries by importing intermediate goods and capital equipment by using used the CH model. Savvides and Zachariadis (2005) expanded the channels of technology spillover originally neglected in the model and concluded that foreign R&D, imports of intermediate and capital goods, and FDI all positively affect total factor productivity in developing countries, especially foreign R&D has the greatest positive impact. Madsen (2007) used a 135-year dataset of technology imports and total factor productivity in OECD countries to test the CH model and found a significant positive correlation between total factor productivity and imports. Coe et al. (2009) expanded the model by controlling the effect of human capital, which identified the significant effect of domestic and foreign R&D capital stock on total factor productivity. Some other scholars gradually integrated the CH model with other models to carry out research work. Fracasso and Marzetti (2015) combined the CH model with the gravity model and found that regional relatively intensive trade flows are more conducive to the cross-border spillover of intellectual capital. Gavazzoni and Santacreu (2019) integrated the CH model with the asset pricing model and argued that countries with a larger stock of R&D capital have less volatile exchange rates and higher stock market returns.

On the other hand, some scholars have questioned the CH model. Lichtenberg and Potterie (1998) argued that there is aggregation bias in the weighting scheme for calculating the domestic R&D capital stock of trading partners in the CH model, and thus proposed alternative weighting schemes to overcome the model bias, further verifying the validity of the CH model. However, Lumenga-Neso (2005) expanded the CH model to remove some of the challenges for the CH model by introducing 'indirect' technology spillovers. It was then found that trade-related R&D can occur even if the two countries have no actual trade activities, and these indirect spillovers are equally important as direct ones in driving up total factor productivity, thus reinforcing the view that trade plays an important role in technology spillover. In addition, Kao et al. (1996) revisited the econometric basis of the CH model and questioned the accuracy of the model after detecting the significant decrease in the weighted foreign R&D stock by revising the estimation method used.

Although the technology spillover effect of international trade has received extensive attention from academia, those directly studying trade barriers and technology spillover remain to be further enriched. A few scholars have conducted relevant studies. Eaton and Kortum (2001) argued that a few developed countries where innovation activities were highly concentrated were engaged in technology spillover by exporting capital goods to other countries, and that trade barriers can hinder this process. Amiti and Konings (2007) used data from manufacturing firms in Indonesia and found that a 10% reduction in import tariffs will increase the total factor productivity of importing firms by 12%. Some scholars have studied the impact of trade policy on technology spillover from the perspective of removing trade barriers and trade liberalization. Hafner (2011) noted that under-developed countries can benefit from R&D expenditures and technological knowledge of developed countries through technology spillover, which can then be reinforced by trade liberalization. Souare (2013) used the data of Canadian manufacturing sectors and found the potential for openness to international trade embodied technology transfer by using the confined exponential and logistic models. Using international production and trade general equilibrium model, it was found that free trade agreements can contribute to the international technology spillover by removing trade and investment barriers (Shikher, 2014). Mutreja et al. (2018) argued that low-income countries would gain access to capital goods from high-income countries with lower trade barriers to, thus increasing their total factor productivity.

To sum up, the technology spillover of international trade and its role in promoting technological progress have become a focal point of scholars around the world. Most scholars have applied, modified and/or extended the CH technology spillover model developed by Coe and Helpman (1995). International technology spillover is strongly concerned on the regional level as the production processes are becoming increasingly fragmented geographically (Audretsch et al., 2014). It is proved that the trading nations specialize according to their relative technology, and in recent years especially developing countries are in process of a structural shift from traditional exports towards technology-intensive intermediate goods trade (Pham and Ulubaşoğlu, 2016; Shrawan and Dubey, 2021). With the development of the division of labor in global value chain, value-added trade accounting framework proposed by Koopman et al. (2014) has been widely used in academic research with GVC.

However, there remains a paucity of research that incorporate value-added trade accounting indices into the CH model and thus better reflect the real source of imports and the real destination of exports from the value-added trade perspective (Poetzsch, 2017; Lee, 2020). Moreover, in the expanding analysis of the international trade technology spillover model, previous studies have tended to focus on the effect of trade policy on technology spillover from the perspective of eliminating trade barriers and promoting trade liberalization, yet relatively few literatures directly studied trade barriers and technology spillover per se. Given this, this paper incorporates the CH and LP models into Grossman and Helpman endogenous growth model from the background based on GVC, and examines the intrinsic mechanism and impact of tariff and non-tariff barriers on international technology spillover in the manufacturing industry in China by combining the gross value of trade and value-added trade.

3. Preliminary Notes

According to the analysis of Grossman and Helpman (1991), total factor productivity (TFP) increases with the variety of intermediate inputs. It is assumed that technological progress is expressed in TFP. Therefore, international trade increases the varieties of intermediate inputs, and the increase of the varieties of intermediate inputs is conducive to the technology spillover of R&D knowledge stock which can reduce the innovation cost, improve total factor productivity and promote technological progress. It is well known that one of the core features of the current GVC era is the trade of intermediate goods. The inputs of multiple varieties and high-quality intermediate import goods can promote total factor productivity, and lead to technological advance and economic growth.

In the existing research on the technology spillover effect of international trade, the CH model that is the econometric model constructed by Coe and Helpman has been widely used, modified and promoted to examine the dependence of a country's total factor productivity on domestic R&D capital and foreign R&D capital by many scholars above mentioned. Therefore, in this paper, based on intermediate goods trade background, we employee the CH model considering with value-added trade and trade barriers for analysis at the industry level, and set the underlying model as Equation (1):

$$lnTFP_{it} = \alpha_0 + \alpha_1 lnS_{it}^d + \alpha_2 lnS_{it}^f + \alpha_3 TB_{it} \times lnS_{it}^f + \alpha_4 X_{it} + \varepsilon_{it} \quad (1)$$

where the subscripts *i* and *t* denote the subdivided industries in China's manufacturing and years respectively, TFP_{it} denotes the total factor productivity of China's manufacturing sector *i* in period *t*, S_{it}^d denotes the domestic R&D expenditure stock of China's manufacturing sector *i* in period *t*, S_{it}^f denotes the weighted foreign R&D expenditure stock absorbed by sector *i* through import in period *t*, and TB_{it} denotes the trade barriers imposed by sector *i* to foreign enterprises. X_{it} acts as the control variable and ε_{it} the random error term.

4. Data and Variables

4.1 Data Resource and Processing

The data for calculating total factor productivity is from the latest WIOD socio-economic accounts released in 2016, and the data for calculating China's domestic R&D expenditure stock are from the China Science and Technology Statistical Yearbook. For the calculation of the weighted foreign R&D expenditure stock, the data for measuring value-added trade are from the UIBE GVC indicator and WIOD released by the Research Institute for Global Value Chains at the University of International Business and Economics, and the GDP of each country are sourced from the WIOD socio-economic accounts, and the R&D expenditure of each country are Main Science and Technology Indicators (MSTI database) and Science Technology and Innovation Outlook 2016 under Science, Technology and Patents column on the OECD website. In the calculation of trade barriers, data for China's tariffs for MFNs are obtained from the World Bank's WITS (World Integrated Trade Solution) database, and the data for anti-dumping tariffs are obtained from the China Trade Remedy Information Network. The data on control variables are obtained from the China Statistical Yearbook of Industrial Economics, UIBE database, UNSD Commodity Trade Statistics Database, WIOD Socio-Economic Accounts, and China Statistical Yearbook. The various price indexes used to deflate the domestic nominal data are obtained from the China Statistical Yearbook.

There are also the following points in the data processing part of this paper that need to be specified:

- In terms of control variables and domestic R&D expenditure stock, we classify the manufacturing industries in China Industrial Economic Statistical Yearbook and China Science and Technology Statistical Yearbook as the corresponding industries in ISIC Rev.4 according to the 2017 release of Industrial Classification for National Economic Activities, which is compiled with reference to yet without equivalent consistency with ISIC Rev.4. For example, in China Industrial Economic Statistical Yearbook and China Science and Technology Statistical Yearbook, the automobile manufacturing industry were not counted separately from the railroad, ship, aerospace and other transportation equipment manufacturing industry until 2012, so we estimate the data of the two industries in years before 2012 according to the proportion in the combined data.

- Missing data for individual years are estimated by the linear growth method.
- For data on open level, we use SITC Rev. 3 as an intermediary to obtain import and export data for manufacturing subsectors, for the product-level data in the UN Comtrade are compiled by HS codes, while the industry-level data by SITC and BEC.
- The conversion of RMB and foreign currency in different databases is based on currency published by the National Bureau of Statistics in the designated year.

4.2 Variables

4.2.1 Total Factor Productivity

In this paper, we calculate total factor productivity with the Solow residual method represented by the specification $TFP = Y/K^{\alpha'}L^{\beta'}$, where Y is the total output of the industry. The reason why we choose total output instead of value added is that this paper involves mainly the growth rate of total manufacturing output. K is the capital input, measure by the actual capital stock data of the industry, and L is the labor input, measured by the number of employees in the industry. Assuming constant returns to scale, α' and β' will be 0.65 and 0.35 calculated.

4.2.2 Domestic R&D expenditure stock

In order for reflecting the actual R&D expenditures in each period, it is necessary to deflate the nominal R&D expenditures with the R&D price index. This paper adopts the cost-input price index method to construct the R&D price index. According to the components of internal expenditure of R&D funds by industry in China from 2000 to 2014, the urban consumer price index substitutes for the wage index of R&D personnel and corresponds to the labor cost, the industrial producer purchasing price index corresponds to the intermediate input cost, and the fixed asset investment price index corresponds to the fixed asset cost (Chen and Hou, 2019). According to the proportion of each cost to the internal outlays of R&D funds in each year, weights 0.3, 0.3 and 0.4 are taken respectively, so as to obtain the R&D price index of each industry in a calendar year relative to 2015, and thus the internal R&D expenditure of each industry in a calendar year with 2015 as the base period (as shown in Figure 1). Then, the perpetual inventory method can be used to convert the domestic R&D expenditure flow of each industry into stock, i.e., $K_t = (1-\delta)K_{t-1} + I_t$, where K_t and K_{t-1} are the domestic R&D expenditure stocks in years t and $t-1$, respectively, δ the capital depreciation rate, and I_t the domestic R&D expenditure flow in year t.

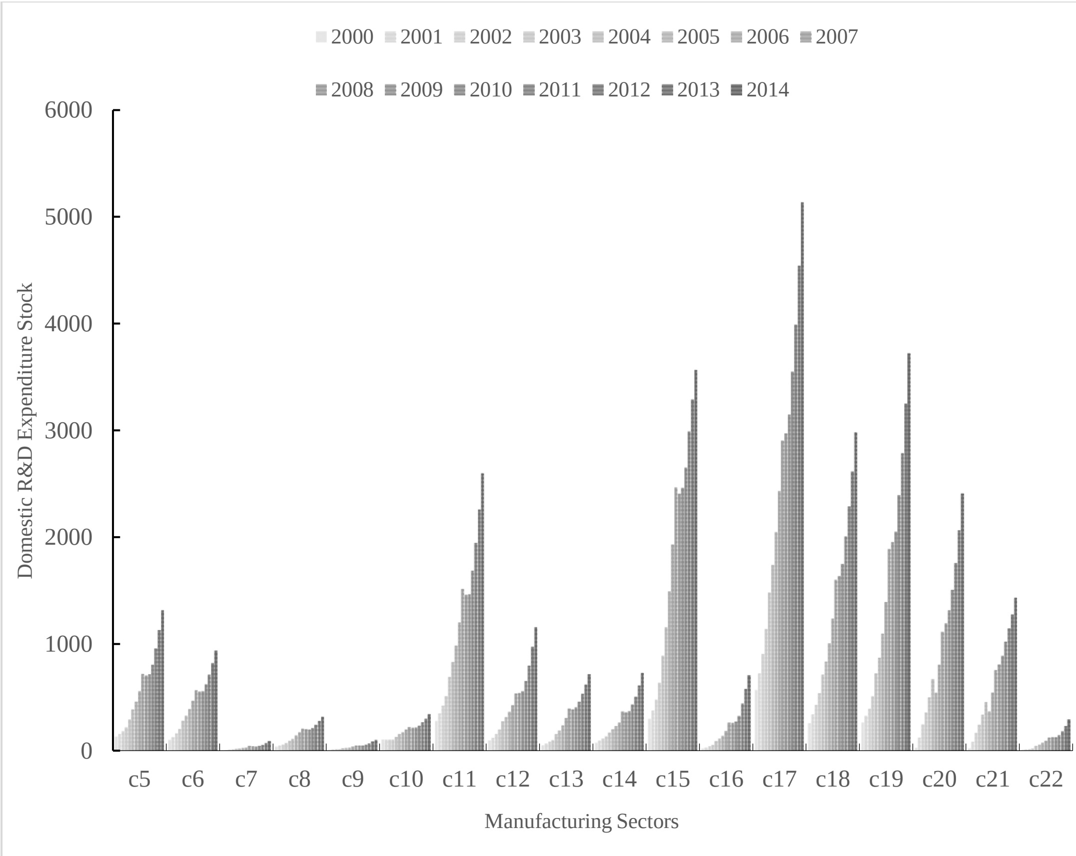

Figure 1: Domestic R&D expenditure stock of China's 18 manufacturing sectors in 2000-2014 Unit: RMB 100 million

4.2.3 Weighted foreign R&D expenditure stock

The CH model's measurement of foreign R&D expenditure stock absorbed through import has been controversial. In the model, $S_{it}^{f(CH)} = \frac{m_{it}}{VA_{it}} \sum_{J \neq I} \frac{m_{iJt}}{m_{it}} \times S_{Jt}$, where, m_{iJt} denotes the imports of manufacturing sector i from country J in year t, $m_{it} = \sum_{J \neq I} m_{iJt}$ denotes the total imports of manufacturing sector i from all trading partners in year t, VA_{it} denotes the value added of manufacturing sector i in year t, and S_{Jt} denotes the domestic R&D expenditure stock in country J. The R&D expenditure stock in each country is calculated with the perpetual inventory method, and the depreciation rate set at 15%. This measuring method has been widely used as it can quantify the foreign R&D expenditure stock to a certain extent, but it has also been questioned by some scholars, especially Lichtenberg and Potterie (1998). They argued that this weighting scheme has 'aggregation bias' and proposed an alternative weighting scheme (LP method), i.e., $S_{it}^{f(LP)} = \sum_{J \neq I} \frac{m_{iJt}}{Y_{Jt}} \times S_{Jt}$, where Y_{Jt} is the GDP of country J in year t. By normalizing the import volume by the GDP of the source country, this method can reflect both the direction of foreign R&D technology spillover and its intensity, which makes it outperform the CH method. With that being said, the LP method for measuring foreign R&D expenditure stock still needs to be improved in that the official statistics of traditional gross trade can no longer reflect the actual situation of the current international trade based on value-added trade. In this regard, we gain insights from fruitful research on the value-added trade accounting framework under the GVC era. In recent years, we have seen ample research decomposing bilateral trade exports from the GVC background and value-added trade perspective, such as Hummels et al. (2001), Antràs et al. (2012), Koopman et al. (2014), and Los et al. (2016). We denote the import value added of each industry from each country as VA_m_{iJt} and substitute it into the LP method, obtaining the method to measure the foreign R&D expenditure stock absorbed by import from the GVC perspective, i.e. $S_{it}^{f(GVC)} = \sum_{J \neq I} \frac{VA\_m_{iJt}}{Y_{Jt}} \times S_{Jt}$ .Table 1 displays the weighted foreign R&D expenditure stock absorbed in 2000 and 2014 through import in 18 sectors of Chinese manufacturing industry based on data of traditional gross trade and value-added trade, calculated through CH method and LP method, respectively.

The analysis reveal results as follows. First, under the same measuring method, the results used traditional gross trade overestimate the weighted foreign R&D expenditure stock absorbed by Chinese manufacturing industry through import compared with value-added trade. However, it should be noted that if the value added of imported products in a certain industry are mainly from some countries with high R&D capital stock, the results of value-added trade will be higher than those of traditional gross trade, and vice versa. Second, compared with the LP method, the CH method overestimates the foreign R&D expenditure stock absorbed by the Chinese manufacturing industry through import from the GVC perspective, which corroborates that the CH method does not reflect the intensity of foreign R&D technology spillover as mentioned above. Third, the ratio of 2014 foreign R&D expenditure stock to 2000 stock calculated by the LP method is overall higher than that measured by the CH method. For instance, for the manufacturing industry, the ratios calculated by the CH and LP methods are 1.62 and 7.67, respectively, the latter of which obviously better reflects the rapid development of China’s imports in this period (according to the China Statistical Yearbook, the ratio of 2014 imports of goods to 2000 imports of goods is 6.46). As seen from calculation formulas, in the CH method, it is not the specific source countries or the variation in shares of China’s import that affects the results, but the change of foreign R&D capital stock; in the LP method, however, the ratio of China’s manufacturing imports to each country’s GDP has changed significantly from 2000 to 2014, which, together with the change of foreign R&D capital stock, becomes the determinant. Hence, this paper substitutes the value-added imports of Chinese manufacturing industries from other countries into the LP method, so that the results can reflect both the direction of foreign R&D technology spillover and the actual intensity of the spillover and to the largest extent stimulate the actual situation among the results listed in Table 1.

Table 1: Weighted foreign R&D expenditure stock and the ratio of China's 18 manufacturing sectors in 2000 and 2014 Unit: million dollars.

Data	Traditional gross trade data			Value-added trade data			Traditional gross trade data			Value-added trade data		
Method	CH method			CH method			LP method			LP method		
Variables	$S_{2000}^{f(CH)}$	$S_{2014}^{f(CH)}$	$\frac{S_{2014}^{f(CH)}}{S_{2000}^{f(CH)}}$	$S'^{f(CH)}_{2000}$	$S'^{f(CH)}_{2014}$	$\frac{S'^{f(CH)}_{2014}}{S'^{f(CH)}_{2000}}$	$S_{2000}^{f(LP)}$	$S_{2014}^{f(LP)}$	$\frac{S_{2014}^{f(LP)}}{S_{2000}^{f(LP)}}$	$S'^{f(LP)}_{2000}$	$S'^{f(LP)}_{2014}$	$\frac{S'^{f(LP)}_{2014}}{S'^{f(LP)}_{2000}}$
c5	3439.85	13199.24	3.84	5183.36	12836.64	2.48	477.10	5157.07	10.81	609.61	5247.68	8.61
c6	7173.71	11276.71	1.57	10610.25	12234.89	1.15	1577.70	5435.68	3.45	1600.32	5009.23	3.13
c7	5054.30	8418.55	1.67	7283.43	13113.28	1.80	193.05	1080.73	5.60	226.59	1311.77	5.79
c8	8809.46	20759.60	2.36	11176.81	23829.60	2.13	282.50	1447.47	5.12	300.31	1442.38	4.80
c9	5867.68	12262.50	2.09	7268.94	13154.81	1.81	171.96	608.23	3.54	178.43	590.45	3.31
c10	3564.39	17523.18	4.92	7284.20	27068.43	3.72	210.59	5113.94	24.28	363.14	5784.38	15.93
c11	12146.29	24801.01	2.04	14423.54	24547.48	1.70	1401.01	10706.60	7.64	1367.79	8099.84	5.92
c12	4380.09	13466.72	3.07	7596.95	15481.23	2.04	164.18	1385.43	8.44	210.16	1455.12	6.92
c13	11661.02	21820.05	1.87	13659.69	21549.12	1.58	698.73	4215.21	6.03	659.01	3220.78	4.89
c14	5863.50	9902.00	1.69	8177.59	11671.61	1.43	555.94	4042.83	7.27	665.17	4079.72	6.13
c15	9341.13	18365.17	1.97	12461.68	22854.79	1.83	1187.76	10475.60	8.82	1288.04	10536.48	8.18
c16	11186.80	16384.02	1.46	14155.58	17714.53	1.25	625.53	3562.31	5.69	642.80	3374.06	5.25
c17	40708.62	54455.82	1.34	40710.78	46605.77	1.14	3446.70	42555.54	12.35	2814.22	28798.41	10.23
c18	18631.70	32475.29	1.74	19075.99	28168.75	1.48	1115.75	11386.99	10.21	992.34	8574.68	8.64
c19	14923.55	32233.63	2.16	13527.29	25288.27	1.87	1696.02	15013.14	8.85	1361.33	10614.37	7.80
c20	14132.53	44542.74	3.15	13155.59	25862.99	1.97	652.05	14443.60	22.15	542.06	8703.31	16.06
c21	35694.18	62447.14	1.75	28841.98	39628.13	1.37	452.68	5597.98	12.37	346.75	3738.21	10.78
c22	4005.70	6152.84	1.54	5371.05	7114.51	1.32	330.71	759.28	2.30	352.02	728.82	2.07
Sum	216584.49	420486.21	1.94	239964.70	388724.84	1.62	15239.94	142987.64	9.38	14520.09	111309.69	7.67

4.2.4 Foreign trade barriers

Foreign trade barriers include tariff barriers and non-tariff barriers. For tariff barriers, in view of the availability of data, we use the average tariffs established by China for the most favored nations (MFNs). For non-tariff barriers, anti-dumping is the most used by governments (Sun and Lee, 2017). And in order to quantify the non-tariff barriers, we select industries' average anti-dumping duty rate, out of other main forms of anti-dumping measures such as margin. Table 2 demonstrates the average tariffs for MFNs on imports in 18 sectors of China's manufacturing industry from 2000-2014, which reveals the noted heterogeneity of average MFN tariffs on imports from different manufacturing sectors in China. Specifically, higher average tariffs are seen in c5 (manufacture of food products, beverages and tobacco products), c17 (manufacture of computer, electronic and optical products), and c20 (manufacture of motor vehicles, trailers and semi-trailers), while lower average tariffs are seen in c7 (manufacture of wood and of products of wood and cork, except furniture), c10 (manufacture of coke and refined petroleum products), c12 (manufacture of basic pharmaceutical products and pharmaceutical preparations), and c15 (manufacture of basic metals). Moreover, the average tariffs of China's manufacturing industries showed an overall downward trend during the period, especially after China's WTO accession. Table 3 presents the average anti-dumping tariffs in 18 of China's manufacturing sectors from 2000 to 2014. It can be seen that China's anti-dumping tariffs is characterized by low tariff rate, narrow distribution and low frequency. The low tariff rate is manifested by the mostly between 10% and 30% average tariff rate of China compared with the high tariff rate imposed by some countries on China; the narrow distribution means that China's anti-dumping tariff is mainly concentrated in a few sectors, such as c8 (Manufacture of paper and paper products), c11 (Manufacture of chemicals and chemical products), c15 (Manufacture of basic metals), and c18 (Manufacture of electrical equipment). And low frequency refers to the fact that China only initiated 211 anti-dumping cases against other countries from 2000 to 2014, among which 152 are in c11 (Manufacture of chemicals and chemical products), according to the China Trade Remedy Information Network, compared with yet 394 initiated by the United States and 591 by India in the same period.

Table 2: The average MFN import tariff rate of China's 18 manufacturing sectors in 2000-2014 Unit:%

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean
c5	28.79	27.53	23.60	19.67	18.20	17.06	16.88	16.92	16.61	16.71	16.80	16.80	16.80	16.46	16.11	19.00
c6	23.62	21.65	18.66	15.67	13.56	12.97	12.20	12.29	12.18	12.19	12.20	12.11	12.02	12.39	12.76	14.43
c7	11.69	10.95	8.37	5.78	5.00	4.21	4.64	3.83	4.89	4.98	5.06	5.04	5.02	4.78	4.53	5.92
c8	16.53	15.33	11.75	8.17	6.79	6.01	5.82	5.86	5.77	5.77	5.77	5.78	5.79	5.71	5.62	7.76
c9	15.00	12.50	9.88	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.33	7.41	6.46	5.50	8.14
c10	7.40	7.40	6.87	6.33	6.33	6.21	5.50	6.16	4.97	5.16	5.34	4.71	4.08	4.30	4.51	5.68
c11	11.24	10.26	9.16	8.06	7.70	6.70	7.39	7.56	7.00	6.94	6.88	6.92	6.96	6.96	6.95	7.78
c12	11.83	11.18	7.96	4.73	4.70	4.57	4.68	4.70	4.60	4.62	4.63	4.62	4.61	4.61	4.60	5.78
c13	16.18	15.51	13.53	11.54	10.77	11.73	9.93	10.57	10.52	10.48	10.43	10.43	10.43	10.46	10.49	11.53
c14	16.87	16.36	14.73	13.09	12.58	12.37	12.00	12.65	11.78	11.81	11.83	11.88	11.93	11.57	11.21	12.84
c15	8.27	7.33	6.33	5.33	5.21	5.18	5.04	5.16	5.00	5.01	5.02	4.99	4.96	4.91	4.85	5.51
c16	13.02	12.05	11.38	10.70	10.69	10.42	10.57	10.56	10.12	10.09	10.05	10.05	10.05	9.97	9.88	10.64
c17	15.46	14.56	11.53	8.50	8.16	7.75	7.58	10.43	18.60	19.81	21.01	25.16	29.31	30.36	31.41	17.31
c18	18.21	17.49	15.03	12.56	11.96	11.13	11.58	12.40	10.63	11.03	11.42	11.38	11.34	10.79	10.24	12.48
c19	14.18	13.83	11.35	8.86	8.29	8.16	8.11	8.28	7.47	7.49	7.51	7.49	7.47	7.30	7.12	8.86
c20	36.53	32.26	26.13	20.00	17.73	18.42	13.85	13.56	13.23	13.84	14.44	14.44	14.44	15.41	16.37	18.71
c21	12.41	11.50	11.10	10.69	10.28	10.59	10.47	10.56	10.43	10.43	10.43	10.43	10.43	10.83	11.22	10.79
c22	20.50	19.35	17.20	15.05	14.22	14.01	12.94	13.60	12.04	12.08	12.12	12.11	12.10	12.22	12.33	14.12
average	16.54	15.39	13.03	10.67	9.97	9.71	9.25	9.57	9.62	9.76	9.90	10.09	10.29	10.30	10.32	

Table 3: The average foreign antidumping duties of China's 18 manufacturing sectors in 2000-2014 Unit: %

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
c5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c8	0.00	0.00	0.00	31.52	0.00	25.96	26.40	25.94	0.00	0.00	0.00	0.00	23.36	0.00	13.82
c9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c11	34.50	52.00	0.00	23.00	54.00	123.93	44.00	32.52	24.01	18.41	0.00	7.16	0.00	30.15	49.73
c12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00
c15	20.00	0.00	18.84	18.37	0.00	0.00	0.00	0.00	0.00	0.00	21.98	0.00	0.00	0.00	0.00
c16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.65	0.00	13.60
c17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.65	0.00	0.00	0.00
c18	0.00	0.00	0.00	0.00	0.00	38.00	0.00	0.00	0.00	0.00	0.00	15.52	0.00	0.00	23.80
c19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.05	0.00	0.00	0.00	0.00
c20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00
c21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
c22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.2.5 Control variables

Foreign direct investment (fdi): Denoted by the amount of foreign direct investment in manufacturing sub-sectors. Foreign direct investment promotes the technological progress of enterprises in Chinese mainland through technology spillover, and introduces advanced corporate governance models to promote enterprise efficiency. It thus enhances the total factor productivity of China's manufacturing industry. Openness (open): open is represented by the total amount of imports and exports divided by the value-added of manufacturing sub-sectors. The higher the level of openness of developing countries, the easier it is to absorb technology spillover and knowledge spillover from developed countries, and to achieve technological progress and economic growth. Capital intensity (capital): capital is expressed by the ratio of capital stock to the number of employees in manufacturing sub-sectors. Generally speaking, the higher the capital intensity, the higher the technological level of the industry and the higher the total factor productivity, though capital deepening may also slow down the technological progress. The proportion of state-owned economy (soe): Expressed by the ratio of the number of state-owned enterprises to the total number of enterprises above the designated size in manufacturing sub-sectors, state-owned economy is an important factor that may limit the efficiency improvement of the industry with the redundant number of staff and inefficient management. Enterprise size (size): the larger the size of the enterprise, the easier it is to achieve returns to scale, which is conducive to the productivity of the enterprise. In order to overcome heteroskedasticity and reduce the fundamental unit, the above variables are taken as logarithms. More details and statistical descriptions of each variable are shown in Table 4.

Table 4: Variable explanation and statistical description

Variables Name	Variables Explains	Mean	Sd.
TFP	Total Factor Productivity	11.78	5.51
RDdomestic	Domestic R&D expenditure stock	7181050	9094184
ADD_LP_RDforeign	Foreign R&D expenditure stock calculated by LP method and value-added trade data	3223.56	4037.96
ADD_CH_RDforeign	Foreign R&D expenditure stock calculated by CH method and value-added trade data	19557.76	11282.87
Tradi_LP_RDforeign	Foreign R&D expenditure stock calculated by LP method and traditional gross trade data	4080.87	5801.92
Tradi_CH_RDforeign	Foreign R&D expenditure stock calculated by CH method and traditional gross trade data	20549.15	15737.62
fdi	Foreign direct investment	727.72	823.51
open	Openness	1.21	1.16
capital	Capital intensity	1.58	0.56
soe	The proportion of state-owned economy	0.11	0.11
size	Enterprise size	6.13	7.06
tariff	Average MFN tariff rates	0.11	0.05
AD_tariff	Average anti-dumping tariff rate	0.03	0.12

5. Empirical Results

5.1 Empirical results of the effect of trade barriers on technology spillover in international trade

The results of estimation using two-way fixed effects regression model are presented in Table 5, where Columns (1) - (2) are traditional gross trade data and value-added trade data, respectively, and columns (3) - (4) include control variables. The results indicates that the foreign R&D capital stock absorbed by a country through international trade significantly contributes to the total factor productivity of its manufacturing industry. Moreover, the estimated coefficients of the weighted foreign capital stock calculated using value-added trade data are higher than those of traditional gross trade data, which means that increases the speed of technology spillover. This can be interpreted as that the traditional gross trade data underestimate the contribution of foreign R&D capital stock to the total factor

productivity level of China's manufacturing industry, and that participation in GVCs facilitates technological progress and innovation in importers.
Table 5 shows that the coefficients of domestic R&D capital stock in China-related columns (1)-(4) are significantly negative, demonstrating that the increase of domestic R&D capital stock instead inhibits the growth of total factor productivity in domestic manufacturing industry, which is obviously contrary to common knowledge. Possible reasons include the decrease of production efficiency due to the intensified industrial competition, the low R&D intensity and unreasonable structure of R&D investment in China's manufacturing industry, the excessive focus on applied research instead of fundamental research, and the passive imitation behaviour, etc.

Table 5: Estimation results of technology spillover effect of international trade

	(1)	**(2)**	**(3)**	**(4)**
Constant	-0.4003	-0.3057	1.4450***	1.7340***
	(-0.82)	(-0.6)	(0.43)	(3.91)
Domestic stock	-0.1472***	-0.1820***	-0.1266***	-0.1551***
	(-4.87)	(-5.80)	(-5.31)	(-6.31)
Foreign stock (traditional trade)	0.7031***		0.4690***	
	(21.94)		(13.54)	
Foreign stock (value-added trade)		0.7375***		0.4732***
		(20.56)		(12.39)
fdi			-0.1901***	-0.1969***
			(-5.75)	(-5.72)
open			0.0610	0.0952**
			(1.65)	(2.47)
capital			0.2321***	0.2185***
			(6.04)	(5.48)
soe			0.1439***	0.1389***
			(3.70)	(3.42)
size			0.4267***	0.4835***
			(8.17)	(9.19)
Industry effect	yes	yes	yes	yes
Year effect	yes	yes	yes	yes
F-statistics	126.55	115.62	197.68	182.91
Adjust R^2	0.9390	0.9336	0.9653	0.9625
N	270	270	270	270

5.2 Empirical results of the effect of trade barriers on technology spillover in international trade

Nowadays, the trade frictions generated by intense and regular trade barriers have struck the production network. It is thus worth to estimate the trade frictions's impact on the technology spillover trade international trade. Therefore, this paper integrates the tariff barriers and non-tariff barriers represented by anti-dumping in the model to examine the impacts of tariff barriers and non-tariff barriers on the international trade technology spillover, which are calculated from the traditional gross trade and value-added trade.

Table 6 presented the estimated coefficients of the weighted foreign R&D capital stock calculated with traditional gross trade data and value-added trade data, whose direction and significance are proven to be consistent with that in Table 5. Columns (1) - (2) show that the estimated coefficients of the cross terms formed by tariff barriers and weighted foreign R&D capital stock calculated with traditional gross trade data and value-added trade data are significantly negative, indicating that tariff barriers will significantly impede the international trade technology spillover from either the traditional trade perspective or the value-added trade perspective. Moreover, the absolute value of the estimated coefficients of the value-added trade is larger than that of traditional trade, implying that traditional trade underestimates the cumulative damaging effect of trade barriers on technology spillover in international trade. The underlying reason may be that the frequent cross-border transportation of intermediate goods on GVCs leads to repeated imposition of tariffs, which amplifies the negative effects of trade barriers. Columns (3) - (4) show that the estimated coefficients of non-tariff barriers represented by anti-dumping and the cross term formed by the weighted foreign R&D capital stock calculated with traditional gross trade data and value-added trade data are negative but insignificant. It not only indicates that the current non-tariff barriers have not yet significantly influenced the technology spillover for China's manufacturing in international trade, which echoes with the previously mentioned characteristics of China's anti-dumping tariffs; but also, it also reveals that reducing the abuse and misuse of non-tariff barriers can moderate its negative effects on technology spillover in GVC trade.

Table 6: Estimation results of the effect of tariff barriers on technology spillover of international trade

	(1)	(2)	(3)	(4)
Constant	1.7045***	2.0031***	1.4462***	1.7377***
	(3.94)	(4.55)	(3.34)	(3.91)
Domestic stock	-0.1335***	-0.1625***	-0.1266***	-0.1551***
	(-5.68)	(-6.73)	(-5.30)	(-6.29)
Foreign stock (traditional trade)	0.4762***		0.4690***	
	(13.98)		(13.52)	
Foreign stock (value-added trade)		0.4855***		0.4735***
		(12.94)		(12.37)
tariff×foreign (traditional trade)	-0.0764***			
	(-3.13)			
tariff×foreign (value-added trade)		-0.0889***		
		(-3.41)		
AD_tariff×foreign (traditional trade)			-0.0006	
			(-0.09)	
AD_tariff×foreign (value-added trade)				-0.0023
				(-0.32)
Control variables	yes	yes	yes	yes
Industry effect	yes	yes	yes	yes
Year effect	yes	yes	yes	yes
F-statistics	200.18	186.7	191.78	177.53
Adjust R^2	0.9665	0.9642	0.9651	0.9624
N	270	270	270	270

The results indicate that accelerating for the absorption and iteration of foreign advanced technology and deeply involved in GVC specialization is useful to reduce the negative impact of foreign advanced technology ladder into domestic market. Moreover, aiming at the world frontier technology and increasing the support for basic research and promoting its application transformation, which helps to resist the negative effects of trade barriers.

5.3 Robustness tests

In this paper, we test robustness in three methods—the first one is to adopt random effects model for estimation. The second one is to replace LP method to CH method for calculating foreign R&D capital stock as the core explanatory variable, and substitute it into the regression mode. The last one is to divide the data using 2008 as the time code, and add trade barriers including tariff barriers and non-tariff barriers to control variables for estimation.

As can be seen from Table 7, after replacing the model estimation method, there are only changes in the value but no significant changes in the direction and significance of the estimated coefficients of the core explanatory variables and the introduced cross terms. And after replacing the calculation method of the foreign R&D capital stock weighted by the core explanatory variables, there is still no marked variation in the direction and significance of the estimated coefficients of the core explanatory variables domestic R&D capital stock and the weighted foreign R&D capital stock. But the cross terms of the introduced trade barriers and the weighted foreign R&D capital stock have changed. This confirms from another angle the shortcomings of the CH method in measuring the weighted foreign R&D capital stock, and testifies that the LP method is a more reasonable and effective.

Table 8-9 present the estimation results of the third robustness test, which based on time-division sample data and adding control variables. GVCs trade characterized by intermediate goods trade developed prosperously and expanded rapidly before 2008 when the global financial crisis hasn't happened. While affected by global financial crisis, the global supply and demand for intermediate goods declined significantly, and the global market shrank as well as the extension of global value chain was blocked which led to brief rebound and slow decline in GVCs and significantly reduced ransnational investment activities, affecting the spillover and access of technology, capital, labor and other factors along the GVCs. That’s why taking 2008 as the time code. Although the points are estimated coefficients of cross terms, trade barriers themselves may affect the process of technology spillover for manufacturing. So this study takes them as the control variables in order to further analyse and discuss the robustness of the model.

The direction and significance of estimated coefficients for the weighted foreign R&D capital stock remains consistent in two periods, which is calculated with traditional gross trade data and value-added trade data. This illustrates the strong robustness of technology spillover effect for manufacturing in international trade. After the introduction of tariff barriers, before 2008, tariff barriers significantly inhibited the technology spillover effect for manufacturing industry, reflecting a strong robustness. After 2008, although the cross term coefficient under the influence of tariff barrier is not significant, it also shows a negative effect. After the introduction of non-tariff barriers, the cross term coefficients show insignificant effect, which is consistent with the baseline regression results.

Table 7: Results of robustness test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	random effects model	random effects model	random effects model	random effects model	CH method for calculating foreign stock	CH method for calculating foreign stock	CH method for calculating foreign stock	CH method for calculating foreign stock
Constant	-8.7488**	-9.2495**	-10.6978***	-11.6062***	0.4411	0.1163	0.7196	0.2860
	(-2.17)	(-2.18)	(-2.67)	(-2.73)	(0.54)	(0.14)	(1.03)	(0.38)
Domestic stock	-1.6533***	-1.6988***	-1.4774***	-1.4493***	-0.0963***	-0.1140***	-0.1028***	-0.1172***
	(-4.40)	(-4.32)	(-3.94)	(-3.67)	(-3.03)	(-3.71)	(-3.39)	(-3.94)
Foreign stock (traditional trade)	6.2327***		6.1298***		0.3149***		0.3010***	
	(12.71)		(12.34)		(6.44)		(6.78)	
Foreign stock (value-added trade)		6.3243***		6.0587***		0.3756***		0.3662***
		(11.43)		(10.79)		(6.47)		(6.85)
tariff×foreign (traditional trade)	-1.3757***				0.0204			
	(-2.87)				(0.68)			
tariff×foreign (value-added trade)		-1.8207***				0.0123		
		(-3.56)				(0.42)		
AD_tariff×foreign (traditional trade)			-0.0052				0.0016	
			(-0.04)				(0.23)	
AD_tariff×foreign (value-added trade)				-0.0134				0.0009
				(-0.09)				(0.13)
Control variables	yes	yes	yes	yes	yes	yes	yes	yes
Industry effect	no	no	no	no	yes	yes	yes	yes
Year effect	no	no	no	no	yes	yes	yes	yes
F-statistics					126.57	126.83	126.33	126.74
Adjust R^2	0.7403	0.7002	0.7207	0.6697	0.9479	0.9480	0.9478	0.9480
N	270	270	270	270	270	270	270	270

Table 8: Results of robustness test-Based on time-division sample data and adding control variables before 2008

	(1)	(2)	(3)	(4)
Constant	0.0800	-0.0868	0.5200	0.6210
	(-0.14)	(-0.15)	(-1.02)	(-1.17)
Domestic stock	-0.0642**	-0.0695**	-0.0873***	-0.1020***
	(-2.40)	(-2.50)	(-3.44)	(-3.87)
Foreign stock	0.4700***		0.4510***	
(traditional trade)	(10.48)		(10.04)	
Foreign stock		0.5160***		0.4720***
(value-added trade)		(9.90)		(9.14)
tariff×foreign	-0.4230**			
(traditional trade)	(-2.46)			
tariff×foreign		-0.5740***		
(value-added trade)		(-2.95)		
AD_tariff×foreign			-0.0613	
(traditional trade)			(-0.85)	
AD_tariff×foreign				0.00723
(value-added trade)				(-0.09)
Control variables	yes	yes	yes	yes
Industry effect	yes	yes	yes	yes
Year effect	yes	yes	yes	yes
F-statistics	127.25	120.51	122.60	113.00
Adjust R^2	0.97	0.97	0.97	0.97
N	162	162	162	162

Table 9: Results of robustness test- Based on time-division sample data and adding control variables after 2008

	(1)	(2)	(3)	(4)
Constant	-1.7160	-2.0800	-1.3320	-1.3630
	(-0.87)	(-1.08)	(-0.82)	(-0.86)
Domestic stock	0.0471	0.00137	0.0583	0.0133
	(-0.44)	(-0.01)	(-0.58)	(-0.13)
Foreign stock	0.4410***		0.3800***	
(traditional trade)	(-4.41)		(-4.73)	
Foreign stock		0.5670***		0.4710***
(value-added trade)		(-5.03)		(-5.35)
tariff×foreign	-0.3920			
(traditional trade)	(-0.77)			
tariff×foreign		-0.6480		
(value-added trade)		(-1.22)		
AD_tariff×foreign			0.0548	
(traditional trade)			(-0.72)	
AD_tariff×foreign				0.0977
(value-added trade)				(0.0977)
Control variables	yes	yes	yes	yes
Industry effect	yes	yes	yes	yes
Year effect	yes	yes	yes	yes
F-statistics	348.37	371.42	348.41	370.51
Adjust R^2	0.993	0.993	0.993	0.993
N	108	108	108	108

6. Conclusion

The intermediate trade promotes the development of global value chain, and the accounting of value-added trade can truly reflect the status, benefits of countries and the actual degree of frictions in the global value chain specialization. Through modifying the measurement methods of CH and LP models and taking Chinese manufacturing data as sample, this paper verifies the existence and heterogeneity of international technology spillover effects of traditional gross trade and value-added trade, and investigates the internal mechanism and effect of tariff and non-tariff barriers on technology spillover in manufacturing industry. We came to several conclusions:

- Both the weighted foreign R&D capital stock calculated by traditional gross trade and value-added trade data have a significant effect on the TFP of China's manufacturing industry, that is, the measurement based on value-added trade improves the speed of international technology spillover, but traditional gross trade data underestimate the facilitation effect of foreign R&D capital stock on

TFP. However, at the same time, domestic R&D capital stock significantly inhibits the growth of domestic TFP, in addition, foreign direct investment, capital intensity, the proportion of the state-owned economy, and enterprise size also plays a striking role in domestic TFP.

- No matter from the perspective of traditional trade or value-added trade, tariff barriers highly inhibit the international technology spillover effect of trade, and the traditional gross trade data underestimated the accumulative destruction of trade barriers on the technology spillover effect, but there is no remarkable effect of non-tariff barriers.
- The comparison results show that the index measured by value-added imports data into the LP method can reflect both the direction and the real intensity of foreign R&D technology spillover, which is a relatively accurate indicator and in line with the actual development of China.
- In terms of tariff barriers, the heterogeneity of average MFN tariff rates of different manufacturing industries in China is obvious, and the average tariff rates show a decreasing trend in all manufacturing industries in China during the research period. In terms of non-tariff barriers, China's external anti-dumping tariffs are characterized by a low tax rate, narrow distribution and low frequency.

Our findings have important implications for policymakers. First, it may be important to expand opening-up, oppose trade protectionism, and reduce trade barriers. At the same time, optimize the import trade structure, import more products with higher added value, and create a modern high-quality import system. Second, it should speed up the absorption, induction and update iteration of foreign advanced technologies, deeply participate in the specialized division of labor in the global value chain, and reduce the negative impact of foreign advanced technology entering the country. Furthermore, the country could increase support for basic research, and actively promote the transformation of basic research results to the application side. Third, taking advantage of the opportunities for regional cooperation and development, it could strengthen the complementary development of inter-regional manufacturing industries, weaken the negative impact of trade barriers through regional value chains, as well as strengthen the international technology diffusion effect of manufacturing.

There are several limitations to this study. First, a more detailed analysis could be obtained based on the data at the micro level of manufacturing enterprises or the data from other regions and countries. Second, other common measures of non-tariff barriers could be studied, such as import and export control, technical barriers, environmental barriers, intellectual property protection, etc.

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References

[1] Tsekeris, T. (2017). Global value chains: Building blocks and network dynamics. Physica A: Statistical Mechanics and its Applications, Volume 488, pp.187-204.

[2] Behera, S. R. (2017). Regional foreign direct investment and technology spillover: evidence across different clusters in India. Economics of innovation and new technology, Volume 26, Issue 7, pp.596-620.

[3] Chang, C. L., Chen, S. P., and McAleer, M. (2013). Globalization and knowledge spillover: international direct investment, exports and patents. Economics of Innovation and New Technology, Volume 22, Issue 4, pp.329-352.

[4] Madsen, J. B., and Farhadi, M. (2018). International technology spillovers and growth over the past 142 years: the role of genetic proximity. Economica, Volume 85, Issue 338, pp.329-359.

[5] Chen, X., Wang, X., and Zhou, M. (2019). Firms' green R&D cooperation behaviour in a supply chain: Technological spillover, power and coordination. International Journal of Production Economics, Volume 218, pp.118-134.

[6] Sun, H., Edziah, B. K., Sarkodie, S. A., and Taghizadeh-Hesary, F. (2021). Energy efficiency: The role of technological innovation and knowledge spillover. Technological Forecasting and Social Change, Volume 167, 120659.

[7] Coe, D. T., and Helpman, E. (1995). International R&D spillovers. European Economic Review, Volume 39, Issue 5, pp.859-887.

[8] Idris, Z. Z., Ismail N. W., Ibrahim, S., and Hamzah H. Z. (2021). The impact of high-technology trade on employment. The Journal of International Trade & Economic Development, Volume 30, Issue 4, pp.512-529.

[9] Keller, W. (1998). Are international R&D spillovers trade-related? Analysing spillovers among randomly matched trade partners. European Economic Review, Volume 42, Issue 8, pp.1469-1481.

[10] Souare, M. (2013). Productivity growth, Productivity growth, trade and FDI nexus: evidence from the Canadian manufacturing sector. The Journal of Technology Transfer, Volume 38, pp.675-698.

[11] Xu, B., and Chiang, E. P. (2005). Trade, Patents and International Technology Diffusion. The Journal of International Trade & Economic Development, Volume 14, Issue1, pp.115-135.

[12] Yang, W., Yu, X., Zhang, B. and Huang, Z. Y. (2021). Mapping the landscape of international technology diffusion (1994-2017): network analysis of transnational patents. The Journal of Technology Transfer, Volume 46, pp.138-171.

[13] Grossman, G. M., and Helpman, E. (1991). Innovation and Growth in the Global Economy. MIT Press, Cambridge, MA.

[14] Becker, W., and Peters, J. (1998). R&D-competition between vertical corporate networks: Market structure and strategic R&D-spillovers. Economics of Innovation and New Technology, Volume 6, Issue 1, pp.51-72.

[15] Cincera, M. (2005). Firms' productivity growth and R&D spillovers: An analysis of alternative technological proximity measures. Economics of Innovation and New Technology, Volume 14, Issue 8, pp.657-682.
[16] Coe, D. T., Helpman, E., and Hoffmaister, A. W. (2009). International R&D spillovers and institutions. European Economic Review, Volume 53, Issue 7, pp.723-741.
[17] Fracasso, A., and Marzetti, V. G. (2015). International trade and R&D spillovers. Journal of International Economics, Volume 96, Issue 1, pp.138-149.
[18] Kao, C., Cheng, M. H., and Chen, B. (1996). International R&D spillovers: an application of estimation and inference in panel cointegration." Oxford Bulletin of Economics and Statistics, Volume 61, Issue S1, pp. 691-709.
[19] Lumenga-Neso, O., Olarreaga, M., and Schiff, M. (2005). On 'indirect' trade-related R&D spillovers. European Economic Review, Volume 49, Issue7, pp. 1785-1798.
[20] Savvides, A., and Zachariadis, M. (2005). International Technology Diffusion and the Growth of TFP in the Manufacturing Sector of Developing Economies. Review of Development Economics, Volume 9, Issue 4, pp.482-501.
[21] Hummels, D., Ishii, J., and Yi, K. (2001). The Nature and Growth of Vertical Specialization in World Trade. Journal of International Economics, Volume 54, Issue 1, pp.75-96.
[22] Koopman, R., Powers, W., Wang, Z., and Wei, S. J. (2010). Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains. NBER Working Paper No.16426.
[23] Wang, Z., Wei, S. J., and Zhu, K. F. (2013). Quantifying International Production Sharing at the Bilateral and Sector Level. NBER Working No. 19677.
[24] Johnson, R. C., and Noguera, G. (2012). Accounting for Intermediates: Production Sharing and Trade in Value Added. Journal of International Economics, Volume 86, Issue 2, pp.224-236.
[25] Koopman, R., Wang, Z., and Wei, S. J. (2014). Tracing Value-Added and Double Counting in Gross Exports. The American Economic Review, Volume 104, Issue 2, pp.459-494.
[26] Wang, Z., Wei, S. J., and Zhu, K. F. (2015). Gross Trade Accounting Method: Official Trade Statistics and Measurement of the Global Value Chain. Social Sciences in China (in Chinese), Volume 9, pp.108-127+205-206.
[27] Wang, Z., Wei, S. J., Yu, X. D., and Zhu, K. F. (2017). Characterizing Global Value Chains: Production Length and Upstreamness. NBER Working Paper No.23261.
[28] Lichtenberg, F. R., and Potterie, B. V. P. D. L. (1998). International R&D Spillovers: A Comment. European Economic Review, Volume 42, Issue 8, pp.1483-1491.

[29] Bitzer, J., and Geishecker, I. (2006). What drives trade-related R&D spillovers? Decomposing knowledge-diffusing trade flows. Economics Letters, Volume 93, Issue 1, pp.52-57.
[30] Coe, D. T., Helpman, E., and Hoffmaister, A. W. (1997). North-South R&D spillovers. Economic Journal, Volume 107, Issue 440, pp.134-149.
[31] Eaton, J., and Kortum, S. (1996). Trade in Ideas: Patenting and Productivity in the OECD. Journal of International Economics, Volume 40, Issue 3/4, pp.51-278.
[32] Funk, M. (2001). Trade and international R&D spillovers among OECD countries. Southern Economic Journal, Volume 67, Issue 3, pp.725-736.
[33] Keller, W. (1999). How trade patterns and technology flows affect productivity growth. NBER Working Paper No.6990.
[34] Engelbrecht, H. J. (1997). International R&D spillovers, human capital and productivity in OECD economies: An empirical investigation. European Economic Review, Volume 41, Issue 8, pp.1479-1488.
[35] Madsen, J. (2007). Technology spillover through trade and TFP convergence: 135 years of evidence for the OECD countries. Journal of International Economic, Volume 72, Issue 2, pp.464-480.
[36] Gavazzoni, F., and Santacreu, A. M. (2019.) International R&D Spillovers and Asset Prices. Journal of Financial Economic, Volume 136, Issue2, pp.330-354.
[37] Eaton, J., and Kortum, S. (2001). Trade in capital goods. European Economic Review, Volume 45, Issue 7, pp.1195-1235.
[38] Amiti, M., and Konings, J. (2007). Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. American Economic Review, Volume 97, Issue 5, pp.1611-1638.
[39] Hafner, K. A. (2011). Trade Liberalization and Technology Diffusion. Review of International Economics, Volume 19, Issue 5, pp.963-978.
[40] Shikher, S. (2014). International Production, Technology Diffusion, and Trade. The Journal of International Trade & Economic Development, Volume 23, Issue 1, pp.111-154.
[41] Mutreja, P., Ravikumar, B., and Sposi, M. (2018). Capital Goods Trade, Relative Prices, and Economic Development. Review of Economic Dynamics, Volume 27, pp.101-122.
[42] Audretsch, D. B., Lehmann, E.E., and Wright, M. (2014). Technology transfer in a global economy. The Journal of Technology Transfer, Volume 39, pp.301-312.
[43] Pham, C. S., and Ulubaşoğlu M. A. (2016). The role of endowments, technology and size in international trade: new evidence from product-level data.The Journal of International Trade & Economic Development, Volume 25, Issue 7, pp.913-937.
[44] Shrawan A., and Dubey A. (2021). Technology intensive trade and business cycle synchronisation: Evidence from a panel threshold regression model for India. The Journal of International Trade & Economic Development, Volume 30, Issue 6, pp.906-929.

[45] Poetzsch, C. (2017). Technology transfer on a two-way street: R&D spillovers through intermediate input usage and supply. Review of World Economics, Volume 153, pp.735-751.
[46] Lee, D. (2020). The role of R&D and input trade in productivity growth: innovation and technology spillovers. The Journal of Technology Transfer, Volume 45, pp.908-928.
[47] Chen, Y.F, and Hou R.J. (2019). The estimation of capital stock of research and development in China's manufacturing industry. Studies in Science of Science (in Chinese), Volume 37, Issue 9, pp.1570-1580.
[48] Antràs, P., Chor, D., and Fally, T. et al. (2012). Measuring the Upstreamness of Production and Trade Flows. American Economic Review, Volume 102, Issue 3, pp.412-416.
[49] Los, B., Timmer, M.P., and de Vries, G.J. (2016). Tracing Value-Added and Double Counting in Gross Exports: Comment. American Economic Review, Volume 106, Issue 7, pp.1958-1966.
[50] Sun, J. Y., and Lee, S. (2017). Anti-dumping Duty and Firm Heterogeneity: Evidence from Korea. World Economy, Volume 40, Issue 9, pp.2007-2030.