Trade Structure Optimization, Technological Progress and Green Technological Innovation: The Regulatory Effect of Government Support

Jinhua Sun [1, a], Junyi Li[1, b], Jian Hu[1, c]

[1]School of Management, Chongqing University of Technology, China

[a] sjh1009@163.com, [b] ljyshimmer@163.com, [c] jianhu-hit@163.com

Abstract. This paper studies the influence of trade structure optimization on green technological innovation with the path of technological progress, and introduces government support (low-carbon subsidies and R&D subsidies) into the model to explore its regulatory role in the path of "trade structure optimization-technological progress-green technological innovation", making an empirical test based on the panel data of 30 provinces in China from 2009 to 2019. The results show that the optimization of import and export trade structure can have a positive impact on green technology innovation. The optimization of import and export trade structure further enhances the innovation ability of green technology by promoting technological progress, which plays a complete intermediary role between the two variables respectively. Low-carbon subsidies positively strengthen the impact of import trade structure optimization on technological progress, while the intensity of R&D subsidies will weaken the impact of import trade structure optimization on technological progress to some extent.

Keywords: Trade structure optimization; Technological progress; Green technology innovation; Low-carbon subsidy; R&D subsidy.

1. Introduction

With the development of China's "one belt and one road" initiative, the scale of China's foreign trade has gradually expanded. While promoting the rapid and stable development of China's economy, its double-edged sword effect has gradually become prominent. The high energy consumption and high pollution emissions initially brought by the extensive growth mode with low-cost factors have led to the worsening of environmental pollution. However, with the continuous advancement of the carbon peaking and carbon neutrality goals, the green development of foreign trade has become an important measure to promote the economic development of foreign trade in line with the current wave of green development in the world. The yearbook data shows that China's foreign trade is still dominated by primary products and industrial products currently, and the proportion of high-tech products is still relatively low. However, high-tech products can provide strong external support for China's technological innovation due to their high added value and strong technology spillover effect. Especially, under the guidance of the new concept of green development, it is extremely necessary to exert the spillover effect of foreign high technology to drive high-quality economic development [1][2]. Therefore, to promote the development of green technology innovation in China by optimizing the trade structure and increasing the proportion of high-tech products in foreign trade products is a topic worthy of people's attention. Meanwhile, green innovation, as an emerging technology developed for the balance between the development of science and technology and environmental protection after the national technical level has been rapidly improved, is closely related to the country's technological progress. Therefore, it is also an important step to enrich the research in this field by refining the impact of trade structure optimization on green technology innovation with technological progress as the influence path.

In recent years, our government has successively issued a series of environmental protection policies like financial subsidies, which affects the ability of innovation subjects to absorb technology spillovers brought by foreign trade, namely, to achieve their own technological progress by absorbing and transforming external resources and technologies [3][4]. Therefore, government support can exert certain effects in the influence of trade structure optimization on technological progress. Some scholars think it may exert positive effects [5][6], while some scholars believe that it may exert negative effects [7]. In order to cope with the different viewpoint, this paper divides the government support into two dimensions low-carbon subsidy and R&D subsidy so that the role of government support in the impact of trade structure optimization on technological progress can be clarified.

2. Theoretical analysis and research hypothesis

2.1 Trade Structure Optimization and Green Technology Innovation

This paper divides trade structure optimization based on the dimension of import and export and discusses the relationship between trade structure optimization and green technology innovation [1].

(1)Import trade structure optimization and green technology innovation

Farhani et al(2014) once put forward that import trade can produce technology spillover effect[8], and then some domestic scholars studied the influence of foreign trade on China's technology development and confirmed that it can introduce foreign advanced technology into China, thus driving its technological innovation and progress[9][10]. Compared with industrial products and primary products, high-tech products are more technological with higher added value, resulting in stronger technology spillover effect. Especially, the global environmental problems are becoming increasingly prominent currently, and many developed countries have taken the application of green technology as the main measure to reduce pollution [11]. In this case, Chinese enterprises can learn from foreign advanced environmental protection technologies by importing high-tech products which consume clean energy and produce less pollution, so as to achieve the goal of green technology development.

Additionally, the import of high-tech products can force enterprises to carry out green technology innovation through competitive effects [1]. In order to realize the coordinated development of economic growth and environmental protection, our government has issued a series of environmental protection policies in recent years, including the policy of providing certain subsidies to people who buy electric vehicles for promoting the application of clean energy. In this case, Chinese enterprises will actively promote green technology innovation to gain the market share of electric vehicles, which is the embodiment of the forced effect of high-tech products on China's green technology innovation.

(2)Export trade structure optimization and green technology innovation

With the increasing emphasis on environmental protection in foreign countries, their enterprises have higher environmental protection requirements for their imported products. Therefore, it is inevitable that the sales of industrial products with low added value and high pollution will gradually decrease in foreign markets. In this case, domestic enterprises must optimize the export trade structure and increase the proportion of high-tech products in export commodities, which indispensably requires domestic enterprises to improve their green technology innovation ability.

At the same time, high-tech products have the characteristics of high added value and high technology, resulting in their high attraction in foreign markets. Therefore, the import of them can enable Chinese enterprises to realize the accumulation of technology and funds through exporting products [2], providing necessary resources for enterprises to further develop green technology innovation. Based on the analysis above, the following assumptions are put forward: The optimization of import/export trade structure has a positive impact on green technology innovation (H1a/H1b).

2.2 Intermediary effect of technological progress

(1)Trade structure optimization and technological progress

The knowledge spillover and technology diffusion effects produced by technology foreign trade are beneficial to the technological development of various countries and promote technological progress [12], which are mainly manifested in the following aspects: First, whether it is import or export trade, the exchange of technical products means the exchange of knowledge [13]. Second, the circulation of high-tech products can promote technology diffusion and technology introduction mainly by technology transfer and patent authorization [14], so as to realize technical exchanges and cooperation among countries, thus promoting technological progress [15]. Third, due to the high added value and high-tech characteristics of high-tech products, the import and export of them can promote the accumulation of capital and technology, which then are invested in the next round of technology research and development, thus promoting technological progress [2]. Fourth, the import and export trade of high-tech products can help countries find their own weaknesses in the research and development of high-tech products, assist them find suitable partners in the production and research and development of high-tech products, and promote technical cooperation, achieving common progress in technology [16]. To sum up, the optimization of trade structure can exert positive effect on technological progress.

(2)Technological progress and green technological innovation

Technological progress is the process of integrating knowledge into human capital [17]. The improvement of a country's overall technical level means that it has a strong talent resource reserve, which is conducive to the promotion of green innovation capability. Based on the analysis of endogenous growth theory, we can know that technological progress is the ultimate source of economic growth in a country or region [18]. However, according to the environmental Kuznets curve, when a region's economy develops to a certain level, the public will pay more attention to the environment [19]. In this case, the government will increase the investment in environmental protection in response to people's demand for a high-quality environment. Meanwhile, it will introduce some environmental protection policies to promote innovative subjects to carry out green technology innovation. In addition, technological progress not only means the improvement of a region's innovation ability, but also means that it can provide sufficient technical support for the region's green innovation [20], which is conducive to the low-carbon development of the region. At the same time, dividing regions according to their technological progress and promoting the leading role of technologically developed regions in relatively backward regions through cooperation can promote the coordinated green innovation development among them [20][21]. Finally, some scholars have proved that technological progress can promote green technology innovation by measuring GML index [22][23]. Based on the analysis above, the following assumptions are put forward: Technological progress plays an intermediary role in the optimization of import/export trade structure and green technology innovation (H2a/H2b)

2.3 Regulatory effect of government support

(1)Dimension division of government support

According to the previous research outcomes, we can see that different scholars' views on the role of government support between trade structure optimization and technological progress have not been unified [24][25][26]. On the one hand, it is believed that the government helps innovators to improve their absorptive capacity of knowledge and technology spillovers in the process of high-tech products import and export by providing funds, equipment, policies and improving the market. Therefore, government support may play a positive role in the influence of trade structure optimization on technological progress [5][6][27]. On the other hand, some scholars believe that due to the "crowding-out effect" of government support on R&D investment of innovation subjects and the intervention of market mechanism, it may have a negative impact on the relationship between trade structure optimization and technological progress [28][29]. In order to cope with this difference, this study refers to the research of Qi (2005) and Dong (2021), and divides government support into two main dimensions, namely, low-carbon subsidies and R&D subsidies, so as to clarify the role of government support in the relationship between trade structure optimization and green technology innovation [30][31].

(2)The Regulatory Effect of Low-Carbon Subsidies

The main purpose of low-carbon subsidies is to provide financial subsidies for innovative subjects and encourage them to develop low-carbon technologies and produce low-carbon products, thus achieving the purpose of developing low-carbon economy [31][32]. First of all, low-carbon subsidies can encourage innovators to increase investment in green technology introduction, relieve their financial pressure to some extent, and provide them with the necessary financial support for the introduction of new green technologies [33], and realize the accumulation of green technology capital [31], which will enhance the positive impact of trade structure optimization on technological progress. In addition, low-carbon subsidies are conducive to improving the efficiency of innovation, enhancing the absorption and transformation effect of innovation subjects on the spillover technology brought about by trade opening, so it can also strengthen the positive impact of trade structure optimization on technological progress [34]. Based on the analysis above, the following assumptions are put forward: Low-carbon subsidies positively regulate the relationship between import/export trade structure optimization and technological progress (H3a/H3b)

(3) The Regulatory Effect of R&D Subsidies

Unlike low-carbon subsidies, R&D subsidies fund all R&D activities of innovation subjects. Previous research shows that although R&D subsidies can make up for the funding gap of innovation activities to some extent, they have a strong "crowding-out effect" on the R&D investment of innovation subjects, reducing their ability to absorb and recreate technology, and further weakening the positive impact of trade structure optimization on technological progress to some extent [28]. Furthermore, the government will interfere with the use of R&D subsidies by innovative subjects to a certain extent, and due to the asymmetric information obtained by the government and the market, the innovation activities that receive R&D subsidies may deviate from the market demand, and its innovation output will be difficult to be transformed into commercial value [29], decreasing the enthusiasm of innovation subjects to improve their own innovation output by absorbing external technology, which will have a negative effect on the positive impact of trade structure optimization on technological progress. Based on the analysis above, the following assumptions are put forward: R&D subsidies negatively regulate the relationship between import/export trade structure optimization and technological progress (H4a/H4b)

3. Research Design

3.1 Model Building

In order to test the influencing mechanism of import/export trade structure optimization on green technology innovation and the intermediary role played by technological progress between them, the following econometric model is constructed as follows:

$$lngreen_{it} = \beta_0 + \beta_1 IM_{it} + \beta_2 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$$TFP_{it} = \beta_0 + \beta_1 IM_{it} + \beta_2 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$lngreen_{it} = \beta_0 + \beta_1 IM_{it} + \beta_2 TFP_{it} + \beta_3 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (3)$$

Similarly, as for export trade structure optimization:

$$lngreen_{it} = \mu_0 + \mu_1 EX_{it} + \mu_2 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (4)$$

$$TFP_{it} = \mu_0 + \mu_1 EX_{it} + \mu_2 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (5)$$

$$lngreen_{it} = \mu_0 + \mu_1 EX_{it} + \mu_2 TFP_{it} + \mu_3 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (6)$$

Considering the regulatory effect of government support on the relationship between the optimization of import trade structure and technological progress, low-carbon subsidies and R&D subsidies are introduced into the model respectively, and the improved econometric model is constructed as follows:

$$TFP_{it} = \eta_0 + \eta_1 IM_{it} + \eta_2 LC_{it} + \eta_3 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (7)$$

$$TFP_{it} = \eta_0 + \eta_1 IM_{it} + \eta_2 LC_{it} + \eta_3 (IM_{it} \times LC_{it}) + \eta_4 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (8)$$

$$TFP_{it} = \eta_0 + \eta_1 IM_{it} + \eta_2 RDSUB_{it} + \eta_3 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (9)$$

$$TFP_{it} = \eta_0 + \eta_1 IM_{it} + \eta_2 RDSUB_{it} + \eta_3 (IM_{it} \times RDSUB_{it}) + \eta_4 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (10)$$

$$TFP_{it} = \eta_0 + \eta_1 IM_{it} + \eta_2 LC_{it} + \eta_3 RDSUB_{it} + \eta_4 (IM_{it} \times LC_{it}) + \eta_5 (IM_{it} \times RDSUB_{it}) + \eta_4 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (11)$$

Similarly, as for export trade structure optimization:

$$TFP_{it} = \varphi_0 + \varphi_1 EX_{it} + \varphi_2 LC_{it} + \varphi_3 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (12)$$

$$TFP_{it} = \varphi_0 + \varphi_1 EX_{it} + \varphi_2 LC_{it} + \varphi_3 (EX_{it} \times LC_{it}) + \varphi_4 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (13)$$

$$TFP_{it} = \varphi_0 + \varphi_1 EX_{it} + \varphi_2 RDSUB_{it} + \varphi_3 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (14)$$

$$TFP_{it} = \varphi_0 + \varphi_1 EX_{it} + \varphi_2 RDSUB_{it} + \varphi_3 (EX_{it} \times RDSUB_{it}) + \varphi_4 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (15)$$

$$TFP_{it} = \varphi_0 + \varphi_1 EX_{it} + \varphi_2 LC_{it} + \varphi_3 RDSUB_{it} + \varphi_4 (EX_{it} \times LC_{it}) + \varphi_5 (EX_{it} \times RDSUB_{it}) + \varphi_6 X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (16)$$

Among them, the concrete definition that every variable represents is explained in 3.2 below.

3.2 Variable Defined

(1) Explained variable. Green technology innovation (lngreen): In this study, the green patent inventions in various provinces are searched, classified and sorted based on the patent authorization time according to the classification number of IPC Green Inventory published by the World Intellectual Property Organization (WIPO) [35]. Additionally, green invention patent authorization is logarithmic.

(2) Explanatory variable. Import/Export trade structure optimization (IM/EX): The proportion of high-tech products' imports/exports to the total imports/exports is selected to measure the regional import/export trade structure optimization.

(3) Intermediary variable. Technological progress (TFP): This study refers to existing research [36-39], and uses Solow residual method to calculate total factor productivity, which is used as a variable to measure technological progress.

(4) Regulatory variable. Low-carbon subsidiaries (LC): This variable is measured by the ratio of environmental protection expenditure to total fiscal expenditure in each region [31]. R&D subsidiaries (RDSUB): This paper refers to the method of Wang (2021), and measures the R&D subsidy by the proportion of government funds in the total internal expenditure of R&D funds [40].

(5) Control variable. Regional economic development level (RJGDP): The regional economic development level is measured by the per capita GDP of each region. Industrial structure (INDUS): The industrial structure of each region is measured by the proportion of the output value of the tertiary industry to the total output value of the region. R&D capital investment (RDGDP): The R&D capital investment is measured by the proportion of the internal expenditure of R&D funds in each region to the GDP of that year.

3.3 Data sources

Considering the availability and authenticity of the data, this paper selects the data from 30 provinces and regions in China (except Tibet, China, Hong Kong, Macau, China and Taiwan Province, China) from 2009 to 2019 for empirical research. The data come from the Statistical Yearbook of China, the Statistical Yearbook of China Science and Technology, etc.

4. Empirical results and analysis

This study verified the rationality of the fixed effect model through Hausman test, and the software used is Stata15.1.

4.1 Optimization of import/export trade structure, technological progress and green technology innovation

As shown in Table 1, Model 1, Model 2 and Model 3 report the influence of import trade structure optimization on green technology innovation and the intermediary role of technological progress in the two variables. It can be concluded that H1a and H2a are tested as tenable. Model 4, Model 5 and Model 6 take the optimization of export trade structure as independent variables to study its influence on green technological innovation and the intermediary role played by technological progress in the two variables. It can be concluded that H1b and H2b are tested as tenable.

Table 1 Trade Structure Optimization, Technological Progress and Green Technological Innovation

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	lngreen	TFP	lngreen	lngreen	TFP	lngreen
IM	0.407*	0.514***	0.203			
	(1.76)	(4.09)	(0.88)			
TFP			0.397**			0.361**
			(2.32)			(2.41)
EX				0.602**	0.569***	0.396
				(2.06)	(3.48)	(1.59)
RDGDP	3.250**	-1.689	3.921**	6.700**	1.419	6.188**
	(2.05)	(-1.38)	(2.13)	(2.38)	(1.15)	(2.30)
RJGDP	-0.003	0.008	-0.006	-0.003	0.007	-0.005
	(-0.07)	(0.48)	(-0.17)	(-0.07)	(0.40)	(-0.14)
INDUS	-2.320*	-1.694**	-1.647	-2.468**	-1.834***	-1.806
	(-1.96)	(-2.65)	(-1.53)	(-2.06)	(-2.90)	(-1.62)
_cons	5.755***	2.998***	4.565***	5.700***	2.975***	4.627***
	(11.01)	(9.42)	(9.00)	(10.90)	(9.66)	(9.36)
Regional fixed effect	fixed	fixed	fixed	fixed	fixed	fixed
Yearly fixed effect	fixed	fixed	fixed	fixed	fixed	fixed
N	330	330	330	330	330	330
R2	0.851	0.818	0.858	0.854	0.822	0.860
Adjusted R2	0.845	0.810	0.852	0.848	0.814	0.853
F	72.507	32.746	69.019	87.020	29.779	76.562

Note: T statistics are in brackets, and *, * * and * * represent the significance levels of 10%, 5% and 1% respectively. (Same as the following tables)

4.2 Optimization of Import/export Trade Structure, Technological Progress and Government Support

As shown in Table 2, Model 7-11 examines the moderating effect of government support between import trade structure optimization and green technological innovation. It can be concluded that H3a and H4a are tested as tenable.

Table 2 Import trade structure optimization, technological progress and government support

Variable	Model 7	Model 8	Model 9	Model 10	Model 11
	TFP	TFP	TFP	TFP	TFP
IM	0.472***	0.407***	0.487***	0.563***	0.471***
	(3.70)	(3.31)	(4.21)	(4.91)	(3.95)
LC	-5.047	-4.220			-4.247
	(-1.24)	(-1.34)			(-1.36)
IMLC		78.213**			82.337**
		(2.16)			(2.19)
RDSUB			-0.884**	-0.872**	-0.878**
			(-2.44)	(-2.42)	(-2.50)
IMRDSUB				-6.603***	-8.216***
				(-2.79)	(-3.37)
RDGDP	-1.553	-1.529	-0.856	-1.117	-1.009
	(-1.41)	(-1.47)	(-0.63)	(-0.82)	(-0.87)
RJGDP	0.017	0.016	0.003	0.004	0.012
	(1.26)	(1.13)	(0.19)	(0.24)	(0.89)
INDUS	-1.699***	-1.630***	-1.617**	-1.550**	-1.465***
	(-2.76)	(-2.85)	(-2.69)	(-2.62)	(-2.84)
cons	3.146***	3.133***	3.193***	3.143***	3.269***
	(8.13)	(8.85)	(10.12)	(10.04)	(9.20)
Regional fixed	fixed	fixed	fixed	fixed	fixed
Yearly fixed effect	fixed	fixed	fixed	fixed	fixed
N	330	330	330	330	330
R2	0.826	0.835	0.826	0.828	0.846
Adjusted R2	0.818	0.827	0.818	0.819	0.837
F	28.945	29.067	33.349	35.945	43.315

As shown in Table 3, Model 12-16 examines the moderating effect of government support (low-carbon subsidies and R&D subsidies) between export trade structure optimization and technological progress. It can be concluded that H_{3b} and H_{4b} are tested as untenable.

Table 3 Export trade structure optimization, technological progress and government support

Variable	Model 12	Model 13	Model 14	Model 15	Model 16
	TFP	TFP	TFP	TFP	TFP
EX	0.527***	0.478***	0.501***	0.498***	0.403***
	(3.60)	(3.55)	(3.21)	(3.14)	(3.32)
LC	-4.955	-4.583			-4.788
	(-1.27)	(-1.25)			(-1.27)
EXLC		30.543			28.475
		(1.40)			(1.43)
RDSUB			-0.700*	-0.702*	-0.721*
			(-1.86)	(-1.86)	(-1.93)
EXRDSUB				0.356	0.836
				(0.16)	(0.42)
RDGDP	1.332	1.792*	1.665	1.596	1.846*
	(1.13)	(1.76)	(1.34)	(1.56)	(1.98)
RJGDP	0.016	0.016	0.003	0.003	0.013
	(1.07)	(1.07)	(0.17)	(0.18)	(0.86)
INDUS	-1.829***	-1.817***	-1.757***	-1.755***	-1.735***
	(-3.00)	(-2.97)	(-2.81)	(-2.80)	(-2.84)
_cons	3.122***	3.116***	3.142***	3.146***	3.300***
	(8.39)	(8.47)	(9.97)	(9.87)	(8.56)
Regional fixed	fixed	fixed	fixed	fixed	fixed
Yearly fixed	fixed	fixed	fixed	fixed	fixed
N	330	330	330	330	330
R2	0.830	0.832	0.827	0.827	0.837
Adjusted R2	0.821	0.823	0.818	0.818	0.827
F	36.385	39.124	32.237	37.815	62.265

4.3 Robustness test

First of all, the robust command in fixed effect model ensures that there is no heteroscedasticity in the model. Secondly, the maximum VIF value not exceed 5 ensures no multicollinearity problem in the model. Finally, this study introduces one period lag of the variables to the model [41], and it is tested that the model is stable and credible.

5. Research conclusions

First of all, both the optimization of import trade structure and export trade structure can have a significant positive impact on green technology innovation. Secondly, both the optimization of import trade structure and the optimization of export trade structure have an effect on green technological innovation through technological progress, and technological progress is a complete intermediary. Thirdly, low-carbon subsidies can positively regulate the positive effect of import trade structure optimization on technological progress, while R&D subsidies can negatively regulate the positive effect of import trade structure optimization on technological progress. Finally, neither low-carbon subsidies nor R&D subsidies can play a regulatory role between export trade structure optimization and technological progress.

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